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The impacts of weather forecasts on military operations a system for conducting quantitative near-real time analyses

Butler, Mark D.

Monterey, California. Naval Postgraduate School

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

THE IMPACTS OF WEATHER FORECASTS ON MILITARY OPERATIONS: A SYSTEM FOR CONDUCTING QUANTITATIVE NEAR REAL TIME ANALYSES

by

Mark Butler

September 2005

Thesis Advisor:	Tom Murphree
Second Reader:	Carlyle H. Wash

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13. ABSTRACT (maximum 200 words)

We have developed, tested, and operationally implemented a web based system for collecting and analyzing in near-real time weather forecast and observational data to assess: (a) the performance of forecasts; and (b) the operational impacts of forecasts. A major goal of the system is to quantify the impacts of weather forecasts on the planning, execution, and outcomes of military operations. Our tests and implementation were focused on the METOC support provided by Naval Pacific Meteorology and Oceanography Detachment (NPMOD) Fallon to Naval Strike and Air Warfare Center (NSAWC) operations at Naval Air Station Fallon. Data are collected by NPMOD Fallon and entered via a web interface into a database at the Naval Postgraduate School (NPS) where the data are analyzed and results are reported in near-real time. The results include quantitative assessments of: (1) forecasts used in planning NSAWC missions; (2) changes made during mission planning in response to forecasted weather; (3) deviations from mission plans that occurred in response to weather conditions actually encountered; (4) positive and negative impacts on missions due to forecasts; (5) METOC Tactical Decision Aid forecast accuracy and mission impacts; and (6) forecast performance and mission impacts with respect to specific weather factors.

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THE IMPACTS OF WEATHER FORECASTS ON MILITARY OPERATIONS: A SYSTEM FOR CONDUCTING QUANTITATIVE NEAR-REAL TIME ANALYSES

Mark D Butler
Lieutenant Commander, United States Navy
B.S., Memphis State University, 1992

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NAVAL POSTGRADUATE SCHOOL
September 2005

Author: Mark Butler

Approved by: Professor Tom Murphree
Thesis Advisor

Professor Carlyle H. Wash
Second Reader

Professor Philip A. Durkee
Chairman, Department of Meteorology

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We have developed, tested, and operationally implemented a web based system for collecting and analyzing in near-real time weather forecast and observational data to assess: (a) the performance of forecasts; and (b) the operational impacts of forecasts. A major goal of the system is to quantify the impacts of weather forecasts on the planning, execution, and outcomes of military operations. Our tests and implementation were focused on the METOC support provided by Naval Pacific Meteorology and Oceanography Detachment (NPMOD) Fallon to Naval Strike and Air Warfare Center (NSAWC) operations at Naval Air Station Fallon. In this application of the system, METOC and NSAWC data are collected by NPMOD Fallon personnel and entered via a web interface into a database at the Naval Postgraduate School (NPS) where the data are analyzed and results are reported in near-real time. The results include quantitative assessments of: (1) forecasts used in planning NSAWC missions (e.g., forecast accuracy, probability of detection); (2) changes made during mission planning in response to forecasted weather (e.g., changes in mission schedule, targets, weapons, tactics); (3) deviations from mission plans that occurred during missions in response to weather conditions actually encountered by air crews (e.g., changes in targets, weapons delivered, tactics); (4) positive and negative impacts on mission planning, execution, and outcomes due to forecasts (e.g., missions that avoided or incurred delays, cancellations, inappropriate weapons load outs, missions that might have avoided problems had the forecast been followed by mission planners); (5) METOC Tactical Decision Aid forecast accuracy and mission impacts (e.g., TAWS WOF accuracy, weather impacts on weapon sensors); and (6) forecast performance and mission impacts with respect to specific weather factors (e.g., surface and aloft winds, dust, fog). Numerous analyses of the data collected indicate that weather forecast provided to NSAWC customers have significant positive impacts on mission planning and execution, and the potential to have additional positive

impacts. The system developed in this study can be readily adapted for use at other operational meteorology and oceanography centers, such as other Naval METOC and Air Force Weather units.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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I. INTRODUCTION

A. OVERVIEW

The Chief of Naval Operations (CNO) stated in his Guidance for 2004 (Clark 2004) that the Navy must: “improve output metrics to better define our requirements and resource needs, and instill a culture of improved productivity in everything we do.”

In his 2005 status report on the Naval Oceanography Program, the Oceanographer of the Navy, RADM Tomaszeski wrote (Tomaszeski 2004):

> Our leaders don’t want to hear how important it is to describe the environment, or provide accurate information. Rather, they want to hear how our ‘enabling capabilities’ translate into speed, access, or persistence – how our skills results in advantages in force posture (having the right assets in the right place at the right time for optimal effect), fewer ships sunk, more enemy killed, fewer Blue Force casualties, less time spent in harm’s way, more accurate placement of munitions, etc.

Over the last few years, it has become evident that metrics must become a pivotal tool in the U. S. Naval Meteorology and Oceanography (METOC) community’s efforts to improve support for warfighters, and to assist in the management of decreasing resources for Naval activities. For the METOC community, this means that a METOC metrics program needs to be developed and used as a tool for measuring and improving the community’s performance and productivity. To achieve these goals, a metrics program must be able not only to evaluate METOC products, but also to determine the operational impacts of those products on the METOC community’s warfighting customers.

Several prior studies have indicated that METOC metrics programs have the potential to improve METOC support to warfighters and warfighter performance, for example, by increasing the efficiency and effectiveness of METOC and warfighter operations, improving operational readiness, and increasing safety by decreasing mishaps (Cantu 2001, Martin 2003, Hinz 2004, Jarry 2005). The Naval METOC community can achieve these advantages by

developing a metrics program that accurately gauges the impacts of METOC products on the planning and conduct of warfighting operations.

Previous METOC and Air Force Weather (AFW) metrics studies have been completed by LCDR Jake Hinz, USN, and Captain Jeff Jarry, USAF, while students at the Naval Postgraduate School (NPS). LCDR Hinz developed a set of statistical tools known as the NPS Metric Method, based in part on the National Weather Service (NWS) metrics program. Hinz (2004) applied his set of tools to analyze weather forecasts produced during Operation Iraqi Freedom (OIF) and to estimate the impacts of those forecasts on warfighting operations. His goal was to provide the Commander Naval Meteorology and Oceanography Command (CNMOC) with an analysis of METOC performance and impacts during OIF, and a general method for evaluating METOC forecasts and their contributions to customer operations.

The NPS Metric Method has proven to be extremely valuable but difficult for most operational METOC units to implement in their daily operations. These difficulties involved problems with both data collection and data analysis. These problems and their solutions were anticipated by Hinz (2004), who noted:

> "Typically, operational requirements and the high tempo of forecast production preclude the collection of METOC forecast data and, especially, observational data for forecast verification. When this data is collected, it is rarely tied in any way to specific missions. It is rarer still to find METOC community members that collect data on the possible impacts of METOC conditions and forecasts on operational missions.… In future collection efforts, the forecast, observation, and operations data collected must be more standardized in their formats, and have a clearly defined collection methodology. This will allow easier application of metrics methods, such as the NPS Metrics Method, and faster production of analyzed results for use in decision making."

Jarry (2005) analyzed the performance and operational impacts of mission execution forecasts (MEFs) provided by USAF Combat Weather Teams (CWTs) to the Air Mobility Command (AMC). His primary goal was to create standardized procedures and analysis techniques to ensure that AFW metrics

are relevant to operational improvements and inline with customers' operational requirements. The objectives of the Jarry (2005) study were to:

1. quantitatively assess the performance (e.g., accuracy, skill) of AMC MEFs
2. determine the value added by AMC MEFs to warfighter operations

These objectives were met for AMC MEF available for the study (MEFs from fiscal year 2003). However, the data collection by the CWTs, and the analyses by Jarry (2005) were very labor intensive, and the results of the analyses were available only many months after the data was collected.

The results of both the Hinz (2004) and Jarry (2005) studies clearly indicate there is a need for a more automated and near-real time system for collecting and analyzing the data necessary to determine forecast performance and operational impacts. The purpose of this study was to develop a prototype of such a system. To achieve this objective, the methods developed by Hinz (2004) and Jarry (2005) were merged with information technology tools to develop a METOC metrics system that can be used by operational METOC and AFW units to:

1. efficiently collect forecast, observational, and operational customer data
2. rapidly analyze that data to produce analyses of forecast performance, customer performance, and the operational impacts of the forecasts
3. use the analyses to rapidly produce customized metrics reports for METOC units and their customers

B. METOC AND AFW METRICS

METOC and weather metrics programs have been developed by the NWS, Naval METOC community, and AFW. The goals and basic methods of these programs are similar, but there are significant differences in implementation. The status of the NWS program has been reviewed by Hinz (2004) and Jarry (2005). This section summarizes the most recent efforts in AFW and METOC metrics.

1. Navy METOC Metrics

Hinz (2004) developed a set of metrics tools that he called the NPS Metric Method. He developed his tools based on previous work performed by the NWS with the objective of providing a statistical method to evaluate weather forecasts and their operational impacts. Hinz used Operation Iraqi Freedom (OIF) data compiled during March-April 2003. His objectives were to:

1. develop and evaluate a set of metrics for evaluating METOC forecast performance
2. begin the exploration of METOC impacts on OIF air operations
3. design and test a process by which METOC performance and operational impacts can be measured in the long term to identify needed improvements and challenges to be overcome

The NPS Metric Method is based on a contingency table that contains data on forecasted and observed conditions. The forecasted and observed conditions are categorized as either red, yellow, or green based on a known set of weather criteria for a given type of mission. The comparisons between forecast and observed conditions are represented by forecast-observation (FO) pairs. There are nine possible pairs, including, for example, GG representing a forecast condition of green and an observed condition of green; GY representing a forecast condition of green and observed condition of yellow; etc. The data in the table represents the numbers of forecasts, with these numbers arranged according to the corresponding observations. For example, 12 red forecasts with corresponding red observations (i.e., 12 RR pairs); 15 red forecasts with corresponding yellow observations (i.e., 15 RY pairs); etc. The data in the contingency table can be analyzed in many ways, including for example:

a. Forecast Accuracy (FAC), which compares the number of correct forecasts of a given category to the total number of forecasts in that category that were issued. As an example, FAC for red forecasts would be calculated by:

$$FAC=100* RR/(RR+RY+RG)$$

Here, RR represents the number of correct red forecasts and the denominator represents the total number of red forecasts.

b. Probability of Detection (POD), which compares the number of correct forecasts of a given type of event to the number of events that was observed. As an example, the POD for red events would be calculated by:

$$POD=100*RR/(RR+YR+GR)$$

Here, the denominator represents the total number of red events.

Hinz (2004) demonstrated that forecasts for combat operations could be analyzed to determine forecast performance. His results also indicated that the operational impacts of those forecasts could be quantitatively assessed, if additional operational performance data was collected. Hinz's methods, results, and recommendations represent a major advancement beyond what had been achieved in the relatively few prior METOC metrics efforts.

2. Air Force Weather Metrics

Currently, the AFW metrics program is managed in accordance with Air Force Instruction (AFI) 15-114, Functional Resource and Weather Technical Performance Evaluation 2001 (hereafter referred to as AFI 15-114(2001)). According to this instruction, the goal of the program is to evaluate the overall health of the AFW system and to understand the impacts and effectiveness of the weather support provided at every level of military operations. This instruction requires that three types of forecast verification be performed by participating units:

1. forecast impact on mission execution through operational verification (OPVER);
2. forecast accuracy by terminal aerodrome forecast verification (TAFVER);
3. resource protection effectiveness through warning/advisory verification (WARNVER).

The OPVER or mission execution forecast verification (MEFVER) is performed by categorizing the forecast according to a set of Go and No Go parameters, with Go indicating that the forecasted weather conditions will not negatively impact the mission, and No Go indicating that the mission will be impacted. The forecasted weather conditions are then compared to what was observed. According to Jarry (2005) the forecasting units

- identify the weather phenomena that are most critical to their operational customers
- identify the No Go and Go thresholds their customers want to have applied to those phenomena
- provide MEFs for those phenomena
- provide data to verify those MEFs

In 2005, Captain Jeff Jarry, USAF, performed analysis on MEFVER data provided by the Air Mobility Command (AMC). The statistical analysis consisted of 11 forecast performance and four operational impact metrics. Jarry (2005) defined *operator performance* as:

> A measure of the success or quality of an operation based on subjective or objective methods (e.g., number of missions cancelled, number of missions rescheduled, number of missions flown without delays, number of missions delayed, bomb damage assessment, amount of enemy equipment destroyed, number of training hours flown).

and *operational impact metric* as:

> A metric for determining operational impacts (e.g., mitigation rate, weather delay rate, number of missions saved due to accurate forecasts, etc.). These metrics are generally determined by comparing operational performance data to weather phenomena data or weather forecast performance data.

Additionally, Jarry (2005) defined the following impact metrics.

> Mission Weather Delay Rates: The weather delay rate is the total number of missions delayed due to weather divided by the total number of … missions.

Missions at risk due to weather: An operational impacts metric that describes the number of missions that forecasters deemed to be at risk due to forecasts of adverse weather conditions (e.g., due to a No Go MEF).

The above impact metrics were applied to the AMC MEFVER data with the goals of analyzing the accuracy of the forecasts provided, and the impacts of the forecasts on warfighting operations. Jarry (2005) determined that "the main return on investment in the CWTs probably comes from their forecasts of relatively uncommon, but mission critical, No Go conditions." Based on these results, Jarry (2005) applied several more operational impacts metrics that provided more specific analyses of No Go forecasts.

At one of the AMC units, Global Weather Mobility (WXM), when a No Go MEF was given to mission planners, the forecasters also provided, if possible, with a recommendation for mitigating the negative weather impacts. This recommendation included an alternative mission plan for which conditions were forecasted to be Go. Data was collected on the number of migration forecasts that were provided and accepted by mission planners. These results were then analyzed to determine the mitigation rate and the missions saved by use of the mitigation recommendations, according to the following definitions:

Mitigation rate: An operational impact metric that describes the frequency at which mission planners accepted the advice of forecasters on how to avoid mission delays due to weather. The mitigation rate is the number of mitigation recommendations accepted by mission planners divided by the number of mitigation recommendations made, all times 100. The mitigation rate describes the frequency with which mitigation recommendations were accepted by mission planners.

Missions saved: An operational impact metric that describes the net result of mitigation recommendations that were accepted by mission planners. This metric accounts for the number of mitigation recommendations accepted by mission planners, the accuracy of the MEFs for the original mission plans, and the accuracy of the MEFs for alternate mitigation plans.

From these results, Jarry (2005) determined that additional operational impacts data collection was needed to allow for a thorough metrics program. He recommended that data on the following issues be collected to allow a more complete assessment of operational impacts:

- missions at risk due to weather
- missions delayed due to weather
- phenomena that placed missions at risk
- phenomena that caused mission delays
- mitigations, including MEFs for original and alternate plans
- planner acceptance and rejection of mitigation recommendations
- planner reasons for accepting and rejecting recommendations.

C. BASIC PROBLEMS

The Hinz (2004) and Jarry (2005) studies highlighted the shortcomings of current techniques used to collect and analyze metrics data, and made several recommendations to improve the process. Overall, the recommendations can be divided into four main categories:

1. standardize the data collected
2. automate data collection and analyses
3. reduce the complexity of the system for participating METOC and AFW units
4. reduce the time needed for data analysis and the delivery of metrics results

All four of these categories are inherently linked. For example, to decrease the time required to process the data to achieve near real-time results, automation of the metric system is required. Likewise, to completely automate a metrics system, it is necessary to standardize the data collection process. Thus, to overcome any of these problems, a metric program must make progress in all four categories.

1. Data Standardization

Hinz (2004) found that data standardization is a basic requirement of an effective metric program:

> This standardization will allow corporate knowledge and brand recognition to be portable across the Navy. Second, data from standardized products can be more easily inserted into databases for analysis and archiving. Third, standardized products facilitate the development of performance benchmarks that span the METOC community and that are necessary for setting overall goals, identifying needs (e.g., in research and development education and training), and creating a competitive approach.

Jarry (2005) also noted:

> future analyses of forecast performance and operational impacts data would greatly benefit from more consistent and complete data from the different forecasting units.

It has become clear to implement any successful metric program that the data to be collected and analyzed must be standardized. Without consistent data it becomes difficult to compare data from different forecasting units and to develop effective benchmarks of performance. Additionally, using uniform data allows for more effective automation of data collection and analysis processes.

2. Automation

Not only would the automation of a metric program reduce the amount of manpower required to collect and process the data, but it would also decrease the amount of effort require by the managers to oversee the program. Jarry (2005) stated that a fully automated metric system would allow managers to "spend more time making management decisions and conducting training, instead of manually recording and verifying … data".

AFI 115-114 (2001) calls for a:

> [metric] system that automates all metrics, from data collection and aggregation to data quality control. The end-state will be an automated web-based system with the capability to provide ad hoc analyses and reports (assessments) for all levels of AFW support.

Funding and technology shortfalls and the lack of operational effectiveness databases require a phased approach in order to achieve this vision.

3. Complexity

In the summer of 2004, LCDR Marc Steiner, the USS Saipan METOC officer, contacted Prof. Tom Murphree at NPS about developing a METOC metrics program for the Saipan's upcoming fall 2004 deployment. We (the author, Prof. Murphree, and NPS staff) developed a program for the Saipan using the NPS Metrics Method developed by Hinz (2004). Data was collected and analyzed and reports were issued from NPS to the Saipan. However, the results were incomplete, largely due to the complexity of the process, for both: (a) Saipan personnel collecting the forecast and observational data, and using the resulting metrics; and (b) NPS personnel processing and analyzing the data, and issuing metrics reports. In particular, the shipboard staff had problems applying the relatively academic concepts employed in the NPS Metric Method tool set. Additionally, the USS Saipan group did not have the extra time it needed to completely fully engage in such a project. The end result was that the Saipan's METOC division was only able to collect a relatively limited amount of data. At NPS, the analysis of the data and delivery of reports to the Saipan was inhibited by the time required to ingest and analyze the data and issue metrics results. These problems were due to the awkwardness of the format in which the data was collected and delivered (via emails and postal mail from the Saipan) and analyzed (via Excel spreadsheets and graphics). The NPS side of the process was an adaptation of the system used by Hinz (2004). This system was effective for an academic research approach but proved to be difficult to adapt to an operational setting. Our conclusion was that a new system was needed that would reduce the level of information technology (IT) and data analysis sophistication needed by participating units (e.g., the Saipan), and reduce the amount of effort needed by NPS personnel. This new system should be based on the basic concepts used by Hinz (2004) and Jarry (2005) for assessing forecast performance and the operational impacts of forecasts.

4. Time Required

AFI 15-114 (2001) dictates several phases for achieving the end goal of a fully automated metrics program. Phase 3 of the plan calls for the automation of the operational verification (OPVER) program that would include web-based ad hoc analysis and reports that allow the operational customer access to near real time results.

In the Hinz (2004) and Jarry (2005) studies, the time from the final collection of the metrics data from operational units until a final metrics report was completed ranged from six to sixteen months. In part, these large lag times were due to the academic context in which the studies were conducted. In this context, the development and application of concepts was emphasized, and the goal was to lay the foundation for an operational system that would be developed and implemented in subsequent studies. The Hinz and Jarry studies were successful in reaching this goal, but our initial work with the Saipan made it clear that for metrics program to be effective, the turn around time, from collection of data to delivery of metrics results, must be drastically decreased, with the end goal being near real-time results.

D. SPECIFIC QUESTIONS OF THIS STUDY

1. What Data Needs to be Collected to Determine Operational Impacts?

One of the major steps in developing a metrics program is determining what data must be collected to effectively determine operational impacts. AFI 15-114 (2001) dictates that the weather support team and supported commander will " operationally define weather support effectiveness measures (metrics) and mechanisms to cross feed these metrics to weather support providers in a timely manner. "

Additionally, AFI 15-114 (2001) provides the following suggestions on what mission and weather data could be collected to determine operational impacts:

1. Total number of scheduled missions
2. Total number of missions cancelled due to correct forecasts

3. Total number of missions cancelled despite correct forecasts
4. Total number of missions re-targeted, rearmed (different weapons), or rescheduled due to correct forecasts
5. Total number of missions re-targeted, rearmed (different weapons), or rescheduled despite correct forecasts
6. Total number of missions non-effective or partially effective due to actual weather conditions
7. Total number of missions non-effective or partially effective due to incorrect forecasts
8. For missions that were non-effective or partially effective due to actual weather conditions or incorrect forecasts, identify the specific parts of the missions that were affected

In this study, we addressed the methods for collecting and analyzing all of these types of data, plus additional data for assessing forecast performance, the operational impacts of forecasts, and the operational impacts of specific weather phenomena.

2. How Can Technology be Used to Increase Automation and Turn Around Times?

Leveraging information technology (IT) is an obvious answer to solving the problems of lack of automation and standardization, the complexity of metric programs, and the lag time for final reports. But it is not obvious what IT needs to be leveraged, or how that leveraging should be done to be both efficient and effective. What is known is that a computer based system is needed that would allow for: (a) the collection of metric data with minimal customer effort; (b) the near-automatic processing of the data; and (c) the rapid dissemination of results back to METOC and AFW units and their customers. In this study, we devoted a large amount of effort to identifying, testing, and implementing IT tools for achieving these goals.

3. What Data Collection and Analysis Methods Provide the Clearest Quantitative Assessments of Operational Impacts?

One of the basic problems of any metrics program is determining: (a) how to collect the most useful data, especially operational impacts data; (b) which

analytical methods work best with the data collected; and (c) which analytical methods work best for the participating METOC and AFW units and their operational customers. With the wide range of support products provided by military weather units, these issues can be very difficult to resolve. The data collection and analysis methods used by Hinz (2004) and Jarry (2005) worked well for their particular military operations, units, and customers. But these methods are probably not appropriate for many types of operational impacts data, and for many METOC and AFW units, that were not considered in the Hinz and Jarry studies. In this study, we developed several methods for data collection and analysis, with an emphasis on developing a system that is robust and readily adapted to different units and their customers.

E. GOALS OF THIS STUDY

This study had four main goals, all focused on overcoming the basic problems outlined in the preceding sections. The first goal was to identify the data necessary for quantitatively determining forecast performance and the operational impacts of those forecasts. We pursued this goal by: (a) leveraging what had been learned about data requirements in the Hinz (2004) and Jarry (2005) studies; and (b) working with the intended users of the metrics system developed in this study (i.e., METOC and AFW units) to determine what types of warfighter support they provided, what products they issued, what data they were able to collect, and what metrics results they and their customers needed.

The second goal was to develop an online data collection system linked to an online database for archiving and analyzing the required data into a readily accessible form. Such a system would be well suited for collecting and analyzing standardized data. Additionally, many of the data quality problems that Hinz (2005) found could be eliminated by validating the data as it is being submitted. Hinz (2005) stated that:

> There were some significant data quality challenges in this study. These included problems with incompatible formatting, the need to develop databases prior to conducting data analyses, and uncertainties about the quantity and quality of the observations used for verification.

The third goal was to develop a web-based interface that would provide users with near real-time access to the metrics results (i.e., the results of the data analyses). One of the basic problems with previous metrics efforts at NPS was the delay between the data collecting and the final metrics reports. A web based system for collecting and analyzing data, and reporting metrics results, would allow users access to their metrics results immediately after their data has been entered.

The fourth goal was to develop a final metrics report format that fully supported the needs of the users (i.e., the METOC and AFW units and their operational customers). This goal was developed based on the concept that users know better than anyone else what they need. We would provide guidance to users on what is technically and statistically feasible, and work with users to develop an end product that is accurate, complete, and useful.

II. DATA AND METHODS

A. USS SAIPAN

In the summer of 2004, the METOC division onboard the USS Saipan contacted NPS and asked for assistance in the development of system to measure the performance of their locally generated forecasts, in particular, the accuracy of its forecasts. In response, we proposed to the USS Saipan to develop a web based system to provide: (a) archiving and analysis of the forecasted and observed weather conditions; and (b) delivery of the results from the data analyses. The data collection and analyses were designed so that the metrics methods used by Hinz (2004) could be readily adapted. Our goal was to develop and test a system for implementing operationally the methods used by Hinz. Our focus was on creating a system that would work for operational units such as the Saipan, not on conducting a thorough analysis of the Saipan forecasts.

1. Data

The data consisted of a daily forecast produced onboard the USS Saipan and corresponding hourly weather observations from September and October 2004. The daily forecast was a stoplight (red, yellow, green) forecast valid each day at 1200 UTC with lead times from 6 to 96 hours (Figure 1). The forecast and observation data were available for five types of operations:

- Aviation Operations
- Landing Craft Air Cushion (LCAC) Operations
- Landing Craft Utility (LCU) Operations
- Replenishment At Sea (RAS) Operations
- Smallboat Operations

For each operation type, the forecasts for a given valid time were grouped together, with red, yellow, or green forecasts for each 6 hour period from 6 to 96 hours prior to the valid time.

Weather observations were also collected on an hourly basis. The observations include the following weather parameters:

- Time (UTC)
- Wind speed (knots)
- Visibility (nautical miles)
- Weather phenomena
- Sky condition to include cloud density and height
- Combined seas (feet)

The complete data set consisted of all the forecasts provided while the USS Saipan was underway and the corresponding hourly observations for the months of September and October 2004. The total number of forecasts used for this study was 1440 and observations were 569.

2. Methods

a. Flow of Data and Analysis Results

A web interface was designed that allowed the USS Saipan to remotely enter both forecast and observation data into a database located at NPS (see http://wx.met.nps.navy.mil/~mdbutler/index.html and Figures 2 and 3, please note that areas of the website are password protected). The data was then inserted into a database using a scripting code which was embedded in the web page. The web interface allows users to review data that had been previously entered and to delete any data that may have been entered incorrectly. To accomplish this, the following computer languages were used:

- Hypertext Markup Language (HTML)
- PHP: Hypertext Preprocessor (PHP)
- My Structured Query Language (MySQL)

To better understand why these languages were chosen, a brief explanation of each of them is helpful. All three are open source languages or languages that can be used and manipulated for free as long as it is not for commercial gain.

HTML is the basic language for the development of web pages. It was chosen over other more powerful options such as Extensible Hypertext

Markup Language (XHTML) because of its ease of use and the simplicity of the web pages that needed to be designed.

PHP is a widely used server-side scripting language that can be embedded directly into a HTML webpage. Server-side scripting refers to computer programs that are located in the webpage but are actually run on the web server. By embedding the scripting code in the web page, it allows a developer to create a dynamic web page that is capable of processing user supply information and interacting directly with a database.

MySQL is the most popular open source database system. MySQL is designed to be a relational database, which means the data is stored in individual tables versus being stored as one large group. This storage method allows MySQL to process data faster and more efficiently than otherwise.

All three of the main program languages used had the following additional advantages:

1. Cost. All are free for use in the non-commercial environment. The cost of similar commercial software could easily be several thousands of dollars.
2. Simplicity. All three languages are relatively easy to learn and use.
3. Flexibility. HTML web pages are the standard for web pages and can be viewed on any web browser. PHP and MySQL can be operated on UNIX, MAC, or Windows operating systems. PHP is also compatible with almost any major web server software. For this study, PHP was installed on Apache, Microsoft Internet Information Server (IIS), and Solaris.
4. Speed. Application speed was critical for the web system developed for this project since the system was to be accessed by units underway with poor and slow connections. One of the advantages of using this language configuration is that PHP is a server-side application. This results in a drastic time savings for the types of programs developed for this study.

b. Analysis and Output

Once the web interface was completed, the data was entered into the database. At this point, a PERL executable script was used to convert the hourly observations to red, yellow, and green format to allow comparison to the forecasted data. The forecast information and converted observations were then exported to an Excel file for comparison and analysis to be conducted in accordance with the NPS Metrics Method developed by Hinz (2004). The following metrics were obtained from the data:

- Forecast Accuracy (FAC)
- Probability of Detection (POD)
- Number of Accurate Forecasts (NAF)

FAC and POD were plotted against lead time for each forecast condition and for each operation type. For example, a FAC plot for aviation operations consists of curves representing the accuracy of the red, yellow, and green forecasts, and the mean of these forecasts (the total FAC), at each lead time. Figures 17 and 18 present FAC plots for aviation and LCAC forecasts, respectively, and Figures 22 and 23 depict POD for the same forecast types. NAF was defined as the sum of accurate forecasts provided over a given time frame.

B. NAVAL PACIFIC METEOROLOGY AND OCEANOGRAPHY DETACHMENT, FALLON, NEVADA

In March of 2005, we began discussions with LCDR Alex Cantu, METOC OIC at Naval Pacific Meteorology and Oceanography Detachment, Fallon, Nevada, (hereafter referred to as NPMOD) about the possibility of automating and analyzing the data that NPMOD was collecting to determine the operational impacts of the weather support that it was providing to its main customer, the Naval Strike and Air Warfare Center (NSAWC) at Fallon. NPMOD had developed a basic form for collecting information about the operational impacts that resulted from the weather forecasts and recommendations it provided for the planning of NSAWC missions.

The role of NPMOD in the planning of NSAWC mission is shown in Figures 4 and 5 (Cantu 2005). Understanding NPMOD's role is critical in determining the types and amounts of METOC and customer data that can be collected, and the types of analyses that can be conducted. For example, because of the role of NPMOD forecasters' role in providing forecasts and recommendations to mission planners several days prior to mission takeoff, it is possible to collect data that allows us to determine the number of missions saved and other operational impacts. Thus, we recommended to NPMOD personnel that they adapt the mission saved concept described by Jarry (2005) to determine how their forecasts and recommendations impacted NSAWC mission planning and execution, including such things as changes in mission schedule, weapons selection, target selection, and tactics selection.

Our discussions led to the development of a plan for us to collaborate with NPMOD on developing a system for collecting data, objectively analyzing the data, and producing metrics reports in near real time. This collaboration is still underway as of the writing of this report. The key objectives of this collaboration are assessments of the:

1. performance of the NPMOD local air field forecast for Naval Air Station (NAS) Fallon
2. weather phenomena that affect NSAWC missions being flown at NAS Fallon ranges
3. operational impacts of forecast provided by NPMOD to NSAWC during planning and mission execution

Our goal in working with NPMOD was and is to develop and test a data collection and analysis system that builds on the lessons learned from the Hinz (2004) and Jarry (2005) studies, and from our work with the Saipan. As in the Saipan work, our focus for this study was on creating a system that would work for operational units such as the Saipan, not on conducting a thorough analysis of the NPMOD forecasts. We expect that these more comprehensive analyses will be done in future NPS studies, especially once larger quantities of data have been collected by the system.

1. Data

a. Original NPMOD Data Collection

Prior to the development of the NPS-NPMOD collaboration, NPMOD was collecting information based on the following topics and answers to the following questions:

- Debrief time and location
- Mission type
- Did weather impact the mission?
- Was the mission changed due to weather?
- Were the weapons load-out changed due to weather?
- How did weather impact the mission and what was the impact?

NPMOD was developing procedures for analyzing this information when our discussions with NPMOD began (Cantu 2005). These discussions led to a major revision of the data collection process and the development of a data analysis scheme.

b. Revised NPMOD Data Collection

Our work with NPMOD allowed us to pursue one of the basic goals of this study was to identify the types of data necessary to objectively and quantitatively determine operational impacts. To do so, we applied the lessons learned from the Hinz (2004) and Jarry (2005) studies to the context in which NPMOD was providing METOC support to NSWAC.

One of these lessons was that operational impacts of forecasts could not be determined without knowing the performance of those forecasts (e.g., their FAC and POD). This led us to recommend to NPMOD personnel that they expand their data collection efforts to include forecast and observational data, so that forecast performance could be assessed and compared to operational performance. Without knowing the accuracy of the forecasts provided, it is impossible to fully determine how the forecasts affected mission planning and execution. For example, if negative impacts (red conditions) were forecasted to occur during a mission, and if the mission plan was changed in

response to this forecast, then it would be critical to know if the weather forecast was accurate or not. If the forecast was accurate, then the mission could be classified as a mission saved, meaning that the forecast enabled planners to revise the mission and avoid adverse weather conditions. If the forecast was incorrect, then mission planners were incorrectly guided by the forecast, and the mission plan was unnecessarily altered.

Our discussions with NPMOD led to extensive changes in the data collection process; in particular, the collection of data based on the following topics and answers to the following questions:

- Air group flying
- Mission type
- Date and time of mission takeoff
- During the initial team planning, what weather was forecasted to negatively impact the mission?
- What changes to the mission plan resulted from forecasted negative impacts?
- Were these changes in the mission plan correct for the given the forecast?
- Were these changes in the mission plan given the actual weather encountered?
- Were these changes necessary?
- What were the actual negative weather impacts on the mission?
- What were the weather phenomena that negatively impacted the mission?
- What changes to the weapons plan resulted from Tactical Acquisition Weapons Software (TAWS) predictions?
- Were the TAWS predictions accurate?

The data collection process was also revised to collect data on forecasted and observed sustained wind speed, ceiling, and visibility at the takeoff and landing air field. This data was collected for use in analyzing the performance of the air field forecasts. We discussed with NPMOD personnel the collection of data for analyzing the performance of the forecasts of enroute and

target weather in the Fallon ranges. Unfortunately, very little or no in situ observational data is currently available from the ranges (aside from pilot reports) (Cantu 2005). So we were not able to include this critical data in this study. However, the process developed in this study for collecting and analyzing forecast and observational data for the air field will be directly applicable to range data when it becomes available.

The data collection process is illustrated in Figures 6 – 14 (see also NPS METOC Metrics Support Site, http://wx.met.nps.navy.mil/metrics/index.html). These figures show the nine main data categories (Figure 6) and the associated portions of the online data collection form for each of the nine categories (Figures 7-14). For example, Figure 9 shows the data collected regarding mission changes made during the team planning phase of the NSAWC mission planning process (see Figures 4 and 5).

The data set collected for this study and used to test the metrics data collection and analysis system developed for NPMOD consisted of data for 49 missions conducted by two carrier air wings during operations at NSAWC in May and June 2005. The data collection and analysis system is still being used by NPMOD (Cantu 2005) and will be collecting additional NSACW mission data during 2005 and 2006. This data will be analyzed in future NPS METOC metrics studies.

c. Forecast Verification

The planning forecasts issued during the planning cycle were verified mainly by using pilot reports of weather conditions during their missions. These reports were obtained by NPMOD personnel during mission debriefs (see Figures 4 - 5). The focus of these verifications was on verifying the categorical (red, yellow, green) forecast of negative weather impacts. The air field forecasts were verified using data collected by NPMOD observers and by an automated surface observing system (ASOS) at the NAS Fallon air field. The focus of these verifications was on verifying sustained wind speed, minimum ceilings, and visibility.

2. Methods – Flow of Data and Information

The methods used in collecting and archiving the data for this portion of the study were similar to those used in collecting the data from the USS Saipan. The data was entered into a HTML web page form. Then, using PHP code embedded into the web page, the data was entered into a MySQL database.

The key difference between the Saipan and NPMOD portions of this study was that the Saipan data was processed outside of the web based system, while the NSAWC data was processed in an on-demand format. The on-demand results were obtained by embedding the computer programs used to perform the analyses directly into the results or output web page. The end result was users can view the data analysis results immediately after entering the data.

3. Methods – Analyses and Output

By applying the techniques developed by Hinz (2004) and Jarry (2005), several forecast performances and operational impacts metrics and other tools were included in the analysis part of the web based system for analyzing the data collected. The analyses were divided into three categories: (a) operational impacts; (b) mission planning forecast performance and operational performance; and (c) air field forecast accuracy and probability of detection.

a. Operational Impacts

Three main metrics were developed to assess the operational impacts of the forecasts provided during mission planning: (a) missions saved; (b) weapons saved; and (c) missions and weapons potentially saved. These three metrics are explained below:

> Missions saved. A mission is considered to have been saved if: (a) planners changed the mission in response to an accurate weather forecast; and (b) the mission would have been negatively impacted by weather had the mission not been changed. The possible mission changes include changes in mission schedule, target selection, and tactics selection.
>
> Weapons saved. Weapons are considered to have been saved if: (a) planners changed the weapons in response to an accurate

weather forecast; and (b) the weapons would have been negatively impacted by weather had the weapons not been changed.

Missions and weapons potentially saved. Missions and weapons are considered to have been potentially saved if: (a) an accurate forecast of negative impacts was provided to mission planners; (b) the planners chose not to alter the mission or weapons in response to the forecast; and (c) the mission or weapons selected were negatively impacted by weather.

Several additional metrics were developed to provide more detailed analyses of the data that was collected. These metrics were used to determine: (a) the weather phenomena forecasted and observed to cause negative impacts; and (b) the negative mission impacts that resulted from these weather phenomena.

Weather phenomena forecasted to have negative impacts: These are phenomena that were forecasted to impact missions and weapons, including: excessive surface winds; excessive winds aloft; altitude restrictions due to turbulence, icing, or thunderstorms; reduced surface visibility due to fog, haze, dust storm, or precipitation; or low thermal contrast.

Weather phenomena observed to have negative impacts: These are the weather phenomena that actually impacted missions and weapons, including: excessive surface winds; excessive winds aloft; altitude restrictions due to turbulence, icing, or thunderstorms; reduced surface visibility due to fog, haze, dust storm, or precipitation; or low thermal contrast.

Initial team planning changes: These are the changes that were made to the missions as a result of forecasts provided during the planning phase. These changes include: event delayed or rescheduled, weapons changed for high winds, weapons changed for visibility or ceiling, or other.

Negative impacts resulting from weather: These are the impacts that occurred during mission execution as a result of the weather encountered on the range. These impacts were divided into three categories: (a) changes in schedule; (b) changes on type of war (changes in type of exercise conducted), and (c) partial mission (reduction in mission scope).

b. Mission Planning Forecast Performance and Operational Performance

We compared the accuracy of the mission planning forecasts provided to planners several days before mission takeoff (see Figures 4 and 5) with the mission planning changes to determine the impacts of these forecast on planning. The planning forecasts and planning changes were organized into one of the following five categories:

1. Weather was forecasted correctly and the forecast led to a useful mission change
2. Weather was forecasted correctly but mission planners made no change
3. Weather forecast was incorrect and led to an unnecessary mission change
4. Weather forecast was incorrect but mission planners made no change, and a correct forecast would, if accepted by planners, have led to a necessary mission change
5. Not enough information to determine if the mission change was useful or unnecessary

Additionally, data for the above five categories was subdivided according to the weather phenomena that was forecasted or observed to have a negative impact. For example, missions which fell into category 1, above, were analyzed to determine the number of missions for which accurate forecasts of excessive surface winds were issued and led to a useful mission change.

c. Air Field Forecast Accuracy and Probability of Detection

FAC and POD were calculated for the local air field forecasts, including FAC and POD for ceiling, visibility, and winds.

4. Overview of Data Collection and Analysis

The overall process for collecting and analyzing data, and for issuing analysis reports, is shown in Figure 4. This figure may be deceptive, since the development of this process required us to overcome significant conceptual challenges in determining such things as: what results were needed by NPMOD and NSAWC personnel; what data could be collected and what results could be obtained from the data; how to collect the data without imposing an excessive

additional work on NPMOD or NSAWC personnel; and how to present the results in the most useful forms for NPMOD and NSAWC personnel. In addition, significant IT challenges had to be overcome to make the system; user friendly; flexible to accommodate user requested changes; as automated as possible so the work load on NPS personnel is minimized; capable of providing near real time results; accurate; and robust.

III. RESULTS

A. OVERVIEW

In this chapter, we present the results from our analyses of the data provided by the USS Saipan METOC unit and by NPMOD (see NPS METOC Metrics Support Site, http://wx.met.nps.navy.mil/metrics/index.html). We also present our assessment of the IT system we developed for collecting and analyzing this data. In this chapter, we focus on results that help demonstrate and validate the concept and the implementation of the IT system, including the IT, METOC, and operational issues addressed by the system. As a secondary focus, we also address in this chapter the results of our analyses of the METOC and operational data collected as part of the testing and initial implementation of the system.

B. USS SAIPAN

The daily stoplight forecasts provided by the USS Saipan METOC unit for September and October 2004 were analyzed, and FAC, POD, and NAF were calculated for the five different operations supported by these forecasts and for the three different forecast categories (see Chapter II).

1. Saipan Forecast Performance Metrics

The three forecast performance metrics used in this portion of the study, FAC, POD, and NAF, were plotted against the forecast lead time at six hour intervals. These metrics are useful in assessing forecast performance, but in this case their use is limited by the small number of forecasts in the data set. For example, POD for aviation plot (Figure 22) shows that the probability of detecting a yellow event is 100% at a lead time of 12 hours and 28.6% at a lead time of 18 hours. However, these results are based on only three yellow events at 12 hours and seven events at 18 hours, so they may be misleading.

a. FAC

The FAC graphs for the different Saipan operation types and forecast categories are shown in Figures 17-21. Some of these figures show zero FAC values for some forecast categories. These zero values indicate in

general that no forecasts of those categories were issued for the specified operation type and lead time. This is primarily a result of the small number of forecasts in the data set. The total FAC (mean of red, yellow, and green FAC) is probably the most useful quantity in these figures, given the small number of forecasts being analyzed. Figures 17-21 indicate that the total FAC values for each operation type were primarily driven by one event category. For example, the total FAC for aviation forecasts (Figure 17) was driven by the forecasts of green events because these were the most numerous events. Similarly, total FAC values for LCAC and LCU operations were primarily determined by red events, while yellow and green events occurred much less frequently and had very little impact in the total FAC values. Note that the total FAC was about 40-80% for all operation types. These values are consistent with those found by Hinz (2004) and Jarry (2005) for other METOC and AFW forecasts. The total FAC decreases with increasing lead time for aviation forecasts (Figure 17), but changes little or increases with lead time for the four other operation types (Figures 18-21). This wide variation in the relationship between FAC and lead time for different operation types was also found by Hinz (2004) in his analyses of OIF forecasts. Hinz (2004) provides some possible explanations for increases in FAC with increasing lead time (e.g., greater reliance at short lead times on problematic mesoscale models, greater model adjustment problems at short lead times). These explanations may apply here but with such a small sample size, the reasons are difficult to determine. The FAC values show a marked 24 hour periodicity due to persistence in forecasts (e.g., forecast errors that persist over several lead times) and the daily sampling of forecast and observational data used for our analyses.

b. POD

The POD graphs for the different Saipan operation types and forecast categories are shown in Figures 22-26. These figures are similar to those for FAC (Figures 17-21), for example in the interpretation of the zero values, the similarities to the results of Hinz (2004) and Jarry (2005), etc. As with FAC, the total POD values for each operation type were primarily driven by one

type of event. For example, the total POD for aviation forecasts (Figure 22) was driven by the forecasts of green events because these were the most numerous events. Similarly, total POD values for LCAC and LCU operations were primarily determined by red events, while yellow and green events occurred much less frequently and had very little impact in the overall values.

2. Saipan Data Collection and Analysis System

Overall, the system that was developed to allow for the collection of the forecast and observation data performed well and was brought online relatively rapidly. The main shortcoming of the system was in the analysis and delivery of the metrics report to the Saipan METOC team. There was a delay of approximately three months from the time the data was entered until the final report was delivered to the Saipan. Much of this delay came from starting to work with the Saipan prior to having a fully functional and well tested system. However, some of this delay is inherent in the fully functional system used for analyzing and reporting on the Saipan data. The lessons we learned from dealing with these inherent problems led us to develop a faster and more automated system when we began work with NPMOD.

a. Data Collection and Archiving

For the Saipan system, we began work on the data collection portion of the system in December 2004. Data collection was made operational on the NPS web server by early March 2005. The system was expanded by the end of March to include the ability to review and delete the data as necessary.

The system took the Saipan's hourly observations stored in the database and converted them to stoplight forecast categories (red, yellow, or green) using computer scripts written in PERL. These converted observations and the original forecasts were then exported into Excel spreadsheets for analysis and display. The Excel analyses included: (a) comparisons of the forecasted categories to the observed categories; and (b) calculation of the forecast performance metrics using formulas and macros designed and built into Excel.

In the original system developed for the Saipan, a PERL program was developed that automatically retrieved and decoded the hourly weather observations and then stored the decoded information into the main database. Regrettably, we were unable to use this part of the system because the hourly observations archived by the Saipan were in a nonstandard format.

The results of the Saipan portion of the study moved our overall project much closer to our main goal of developing an automatic collection and archiving system, with near real time analyses. In particular, our Saipan experiences demonstrated some key shortfalls in our approach that were later corrected with the design of the system for NPMOD.

C. NPMOD RESULTS

The results of our metrics support for NPMOD can be divided into two categories, metrics results and computer system results. The metrics results can be subdivided into four areas:

- Operational impacts metrics
- Planning forecast and operational performance metrics
- Weather phenomena metrics
- Air field forecast performance metrics

TAWS and TAWS related data was also collected during this study but only for a small number of missions. Due to the small amount of this data, we did not analyze it in this study. This data will continue to be collected for future air wing deployments and will be analyzed in future studies.

1. Metrics Results - Operational Impacts Metrics

The review of our operational impacts metrics results is divided into three categories: missions and weapons saved, initial team planning changes, and tactical impacts during execution.

a. Missions and Weapons Saved

The changes to mission plans made by NSWAC planners in response to the planning forecasts provided by NPMOD were used to determine the number and percent of missions saved, weapons saved, and missions and weapons potentially saved (see Chapter II, section 3.a for an explanation of

these metrics). Of all missions in our data set, 10 % were saved, 8 % of weapons employed on separate missions were saved, and 18 % of missions and weapons were potentially saved (Figure 27). These results indicate that in 18 % of the missions, the planning forecasts led to an increase in NSAWC's operational performance, and that these forecasts could have done so in an additional 18 % of missions. These increases in operational performance are, or could have been, improvements in scheduling, safety, efficiency, effectiveness through the use of planning forecasts to avoid negative weather impacts. The missions and weapons saved results are summarized in Table 1.

Table 1. Summary of missions saved, weapons saved and missions and weapons potentially saved at NSAWC, Fallon.

	Missions	
	Number	**Percent**
Missions Saved	5	10
Weapons Saved	4	8
Missions & Weapons Potentially Saved	9	18

b. Initial Team Planning Changes

We also analyzed the changes made by NSAWC planners to determine the frequency of weather related changes, and the relationships between the types of change and specific weather phenomena. In 76% of all missions, no change was made to mission as a result of weather forecast. Of the 24% that required a change in response to weather, most (50%, or 12 % of all missions), were changed due to visibility and or ceiling restrictions that would have negatively impacted the weapons that had been planned for the missions. The complete breakdown of initial team planning changes is shown in Table 2 and Figure 28.

Table 2. Summary of number and percent of missions which resulted in a team planning change due to forecasted weather.

	No Change in Mission	Mission Delayed or Rescheduled	Weapons Changed Due to Wind	Weapons Changed Due to Visibility	Other Changes
Number	37	5	1	6	0
Percent	76	10	2	12	0

c. Tactical Impacts During Execution

A number of missions were planned despite forecast of negative weather impacts. For these missions, NSWAC personnel flew pre-mission flights within a few hours of mission takeoff to evaluate the weather conditions and make last minute changes to mission plans in response to the weather conditions observed during the pre-mission flights. These included changes such as: mission delay, change in tactics, change in flight levels, reduction in the scope of the mission, and mission cancellation. We analyzed these mission changes to determine the frequency of the specific changes and to later relate these changes to forecast accuracy and specific weather phenomena. The most common change (18% of missions) was a switch to a high war mission (increase in flight altitude), with the next most common change (14% of missions) being cancellation. Table 3 and Figure 29 summarizes the results for all changes made in response to pre-mission weather observations.

Table 3. Summary of the number and percent of tactical mission impacts that resulted from weather during the missions.

	Missions	
	Number	**Percent**
No Impact	23	47
Delay of Mission	2	4
Cancellation of Mission	7	14
Other – Schedule	0	0
Low War	2	4
High War	9	18
Split War	5	10
Other – War	2	4
Partial No Strike	2	4
Partial No Bombs	4	8
Partial Missed	0	0
Other - Partial	0	0

2. Metrics Results – Planning Forecast and Operational Performance Metrics

To determine the effectiveness of the weather support provided during the mission planning phase, we compared information about planning forecast accuracy with information about planning changes. These comparisons allowed us to identify relationships between forecast performance and operational performance. For example, they allowed us to determine cases in which an accurate forecast of negative weather impacts was issued but planners did not alter their plans to account for negative weather conditions, and mission performance was reduced because of accurately forecasted negative weather conditions. These results are summarized in Table 4.

Table 4. Summary of the relationships between planning forecasts and planning changes by number and percent of missions.

	Missions	
	Number	**Percent**
No change made during team planning	27	55
Weather was forecasted correctly and led to a successful mission change	9	18
Weather was forecasted correctly but mission planner made no change	9	18
Weather forecast was incorrect and led to an unnecessary mission change	2	4
Weather forecast was incorrect, and a correct forecast would, if accepted by planners, have led to a necessary mission change	0	0
Not enough information to know if decision was good or bad	1	2
None of the above	1	2

To provide more insight into the weather conditions that led to negative weather forecasts and actual negative weather impacts, we related specific weather phenomena to the missions that fell into categories 2-5 in Table 4. For example, the nine missions in which "Weather was forecasted correctly and led to a successful mission change" were categorized according to their associated negative weather phenomena. This led, for this example, to the determination that for all nine of these missions, negative impacts due to cloud layers and cloud thickness were accurately forecasted and planners made necessary changes in response to those forecasts. The results of these analyses are summarized in Table 5.

Table 5. Summary of the relationships between planning forecasts and planning changes by weather phenomena forecasted to have negative mission impacts.

		Surface Wind	Aloft Wind	Altitude	Clouds	Visibility
Weather was forecasted correctly and ed to a successful mission change	**Number**	5	1	5	9	7
	Percent	56	11	56	100	78
Weather was forecasted correctly but mission planner made no change	**Number**	0	0	1	7	2
	Percent	0	0	11	78	22
Weather forecast was incorrect and led to an unnecessary change.	**Number**	2	2	1	1	1
	Percent	100	100	50	50	50
Weather forecast was incorrect, and a correct forecast would have led to a necessary mission change	**Number**	0	0	0	0	0
	Percent	0	0	0	0	0

3. Metrics Results – Weather Phenomena Metrics

Analyses were also conducted to identify the weather phenomena that were forecasted to cause negative impacts and that actually did cause negative impacts. The weather phenomenon that was most commonly forecasted to cause negative impacts, and that actually did so, was cloud layer thickness. This phenomenon was forecasted to impact 41% of the missions and actually impacted 27% of them. The next most common phenomenon was reduced surface visibility due to fog, haze, dust storm, or precipitation. Reduced surface visibility was forecasted to impact 22% of all missions and actually impacted 14%. The complete breakdown by phenomenon of forecasted negative impacts is shown in Table 6 and Figure 30. The corresponding results for observed negative impacts are shown in Table 7 and Figure 31.

Table 6. Summary of the number and percent of missions forecasted to be impacted by specific weather phenomena.

<u>Forecasted</u>	**Surface Winds**	**Aloft Winds**	**Altitude Restrictions**	**Cloud Thickness**	**Surface Visibility**	**Other**
Number	8	4	8	20	11	1
Percent of Missions	16	8	16	41	22	2

Table 7. Summary of the number and percent of missions observed to be impacted by specific weather phenomena.

<u>Observed</u>	**Surface Winds**	**Aloft Winds**	**Altitude Restrictions**	**Cloud Thickness**	**Surface Visibility**	**Other**
Number	5	0	4	13	7	1
Percent of Missions	10	0	8	27	14	2

4. Metrics Results – Air Field Forecast Performance Metrics

We calculated FAC and POD for the NPMOD forecasts for the NAS Fallon air field. Observational data from an automated observing system, and from NPMOD personnel was available for this location. FAC and POD were calculated for each of three weather parameters: sustained winds, minimum ceiling, and visibility. The results are shown in Table 8.

Table 8. Forecast accuracy and probability of detection results for the NAS Fallon air field for each of three forecasted weather phenomena.

	Wind	**Ceiling**	**Visibility**
FAC (%)	92	82	100
POD (%)	100	68	0

5. Computer System Results

The web-based system developed in support of NPMOD is based on the system developed to support USS Saipan, but has three main improvements: (a) the automation of data collection and analysis; (b) the on-demand, or near real-

time, results; and (c) a web-based output report tailored to meet the specific requirements and goals of NPMOD. The development of the NPMOD system required a tremendous number of web pages and computer scripts, over 35 for the output reports alone. An example of the computer code use to produce an output report is provided in Appendix B. Despite the complexity of the design and development of the system, it has proven to be very robust, has required little additional redesign, and has been very positively reviewed by users at NPMOD.

However, several improvements to the system were requested by users once the system was made operational at NPMOD. One improvement would be to increase the query capability of the web interface to give users more capabilities in searching the archived data. Presently users can only sort the data by individual air wings or by all air wings. An expanded search function would allow users to sort results by month or other time frames and other more specific searches. An additional recommendation is to give the user the ability to edit the data associated with a specific mission. Currently the program only allows for the review and deletion of data but does not permit editing of data. We expect that these improvements will be made in the near future, after the completion of this study.

a. On Demand Results

Unlike the USS Saipan data analyses, which was done offline using Excel spreadsheets, the analyses of NPMOD data are incorporated directly into the user web-interface. By embedding PHP scripts that perform the analyses and deliver the results directly in the output web page, users are able to view the results immediately after the input data has been entered. The online data entry, automated online data analyses, and automated near real time reporting of results allows the users of the system to be relatively independent of the system designers. This independence is a critical for operationally implementing the system with other METOC and AFW units.

b. Tailored Output Reports

Through discussions with NPMOD (Cantu 2005), an output report was designed to provide them with the specific metrics content and format that were needed by NPMOD managers and its NSAWC customers. This tailored report was developed and is used to provide feedback on NPMOD and NSAWC performance, to detail operational impacts of support provided, and to allow for metrics results to be included in briefings to newly arriving air wings and their METOC support teams. The reports can be generated at the system web site for various combinations of data (e.g., reports for individual air wings, for combinations of air wings, or for individual months). A sample output report is shown in Figure 32.

IV. SUMMARY, DISCUSSIONS AND RECOMMENDATIONS

A. SUMMARY OF PROCEDURES AND RESULTS

This study successfully developed, tested and implemented a web-based system for collecting and analyzing forecasts and observations to determine forecast performance and the operational impacts of weather support (see NPS METOC Metrics Support Site, http://wx.met.nps.navy.mil/~mdbutler/index.html). This system provides near real-time or on-demand results for the end user. While several Naval units participated in this study, the main focus was NPMOD which provides weather support to the NSAWC. The implementation of the system allows NPMOD personnel to enter data remotely and view their results on-demand via the internet. The system has become an integral part of the planning and execution cycle at NMPOD (Cantu 2005).

We applied several forecast performance and operational impacts metrics used by Hinz (2004) and Jarry (2005), and also developed several new metrics. The metrics used in this study allowed us to quantitatively assess:

1. performance of the forecasts used in planning NSAWC missions (e.g. forecast accuracy, probability of detection)
2. impacts of forecasts on mission planning (e.g. changes in mission schedule, targets, weapons, tactics)
3. deviations from mission plans that occurred during missions in response to weather conditions actually encountered by air crews (e.g. changes in tactics, targets, weapons use)
4. positive and negative impacts on mission planning, execution, and outcomes due to forecasts (e.g. missions that avoided or incurred delays, cancellations, inappropriate weapons load outs, missions that might have avoided problems had the forecast been followed by mission planners)
5. METOC tactical decision aid forecast accuracy and mission impacts (e.g., TAWS WOF accuracy, weather impacts on weapon sensors)

6. forecast performance and mission impacts with respect to specific weather factors (e.g., surface and aloft winds, dust, fog)

B. ADDITIONAL WORK COMPLETED

In addition to the study described in the preceding sections, we also worked on several related but less extensive studies. One of the studies was in support of a request from the METOC team onboard the USS Nimitz. This team wanted assistance in developing an automated system for collecting and analyzing its air operations brief which was given several times a day. A basic system was developed through collaboration between the USS Nimitz and NPS to allow for the collection of the brief, but the complete system to archive hourly observations and perform analyses has not yet been implemented due to time constraints.

Preliminary work was also completed on a system to allow for the automated collection of both TAFs and hourly observations for U.S. Naval air facilities, with the goal of using this data to perform automated TAF verification. The ultimate goal of this work was to develop a system that would allow for the automated TAF verification for all U.S. Navy air facilities and local forecast and warning verification for all U.S. Navy shore facilities. The data collection and archiving part of the system was created, but the verification part of the system remained in development due to time constraints.

Finally, at the request of the commanding officer at Strike Group Oceanography Team Norfolk, CDR Steve Woll, software was installed at NPS on the SIPRNET to allow for the porting of metrics systems to the classified side. This was a first step in adapting the automated online metrics system described in the preceding system for use in a classified setting.

C. RECOMMENDATIONS

The web-based system that was developed for this study is in operational used by NPMOD personnel in support of NSAWC missions. The missions being supported for this study are being conducted by Navy strike air wings preparing for upcoming deployments. Also at this time, METOC forecasters are being

deployed to accompany the air wings as they train at NAS Fallon (Cantu 2005). Eventually, these same forecasters will join the air wings as they are forward deployed. One of key recommendations for this study is to familiarize the deploying forecasters with this system so that data from real world naval missions can be collected as air wings and their forecasters deploy together.

A second recommendation is to adapt the web-based system to other types of military weather support. For example, the current system could be easily adapted to collect and analyze the performance of the stoplight or Go/No Go forecasts produced by many METOC and AFW units. This would allow many units to have their forecasts analyzed and reported on in near real-time with relatively little effort by unit personnel. Presently, many units do not even attempt to evaluate their forecasts because they perceive the learning and development curve to be very steep, and the implementation costs very high. The system developed in this study greatly reduces the knowledge and skills required of users by automating the main steps needed to conduct forecast performance assessments.

A major feature of the system we have developed is its ability to assess the operational impacts of METOC support. As far as we have been able to determine, there is no comparable process, especially such an automated near real time process, in existence any other civilian or military organization. Thus, we recommend the adaptation of this system to other military and civilian organizations for the purpose of assessing how operations are affected by METOC conditions and METOC forecasts. A prime candidate for adaptation of the system is air combat units and Air Force combat weather teams at Nellis Air Force Base, Nevada, where strike training similar to that at NAS Fallon is conducted. With minor adjustments to the data being collected, similar operational impacts and forecast accuracies reports could be produced for USAF missions.

We also recommend training permanent personnel to continue to develop and maintain the current system. One of the major concerns of the NPMOD

personnel was that the system that was developed for this study would no longer be available after the completion of the study. While the system was designed to allow for continued use after the study was completed, additional work will be required to maintain or expand the system to other units. The continuity of operations provided by permanent personnel would be pivotal to the continuing success of this program.

Finally, we recommend centralizing research, development, and testing of forecast performance and operational impacts metrics systems at NPS. This would enhance the standardization of data, analysis procedures, results, and reports. It would also promote efficiency by having faculty, researchers, and METOC and AFW officers at NPS to focus on research and development, and allowing operational METOC and AFW units to focus on providing customer support. Additionally, due to Department of Defense Information Technology 21 (IT21) restrictions, much of the software used in the NPS automated online system work is unavailable to most military units. Alternative software that is available to these units is much less suitable for such systems.

D. FUTURE WORK

After the successful implementation of the system several additional units were interested in participating in the study, but due to time constraints the study was unable to fully accommodate these requests. These willing participants provide excellent opportunities to expand the current system and develop a fleet wide METOC metrics program. We expect that these opportunities will be pursued through additional collaborations between NPS and METOC and AFW units. One such additional collaborative project is currently underway. In this project, NPS will work with U.S. Air Force combat weather teams (CWTs) in the Air Combat Command to adapt the system employed at NAS Fallon for use by the CWTs and their customers.

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APPENDIX A. FIGURES

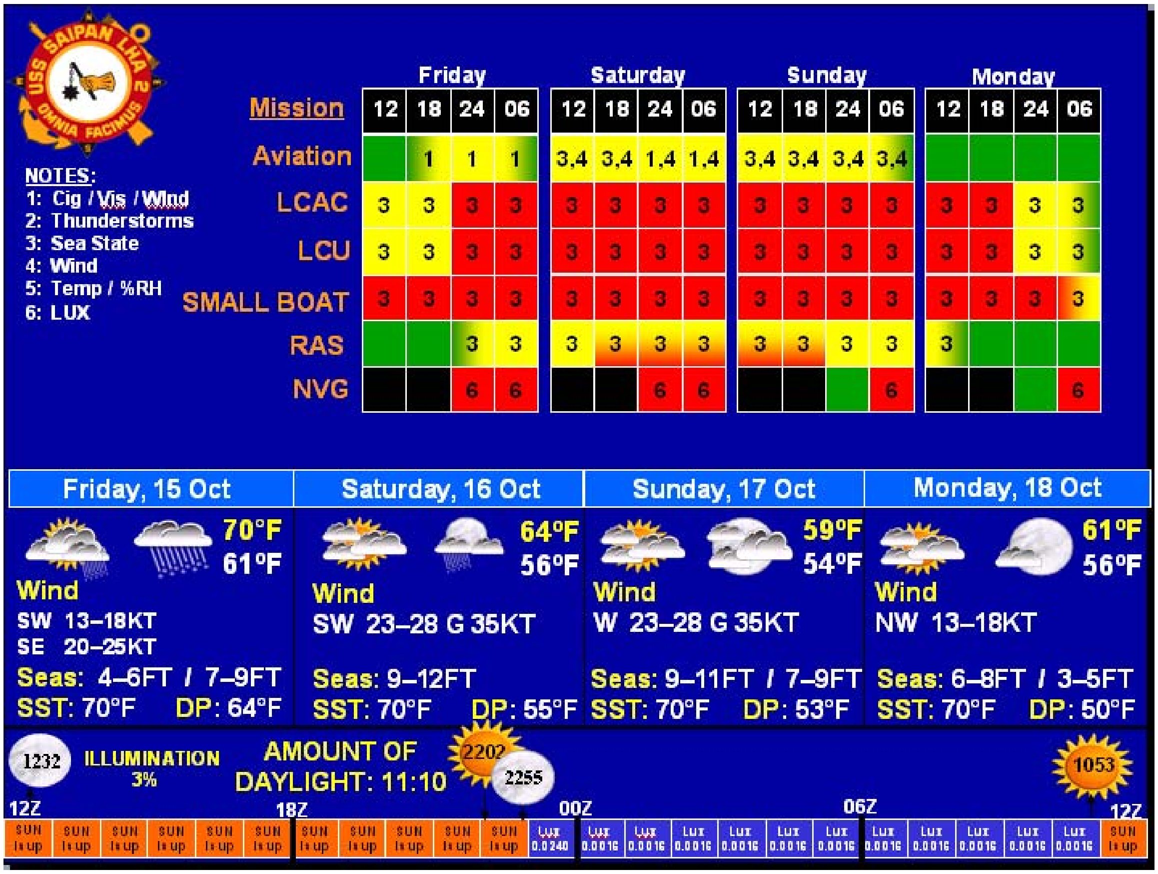


Figure 1. Example of USS Saipan daily 96 hour forecast for aviation, LCAC, LCU, smallboat, and RAS operations.

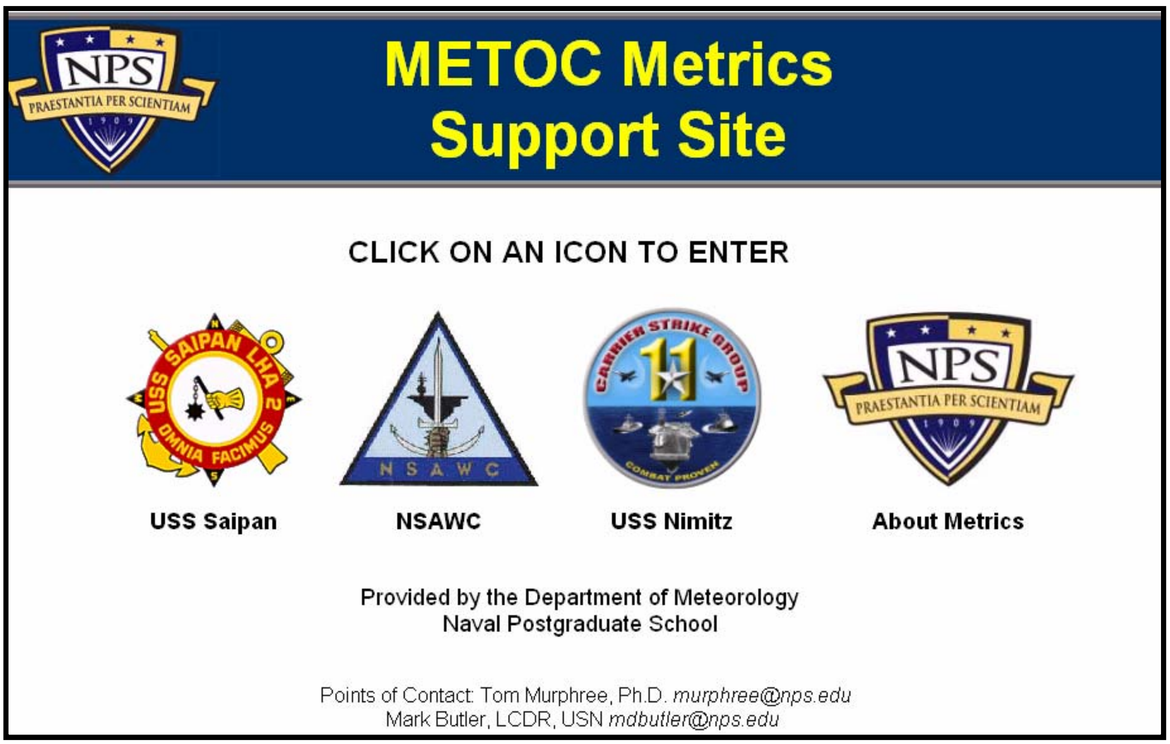
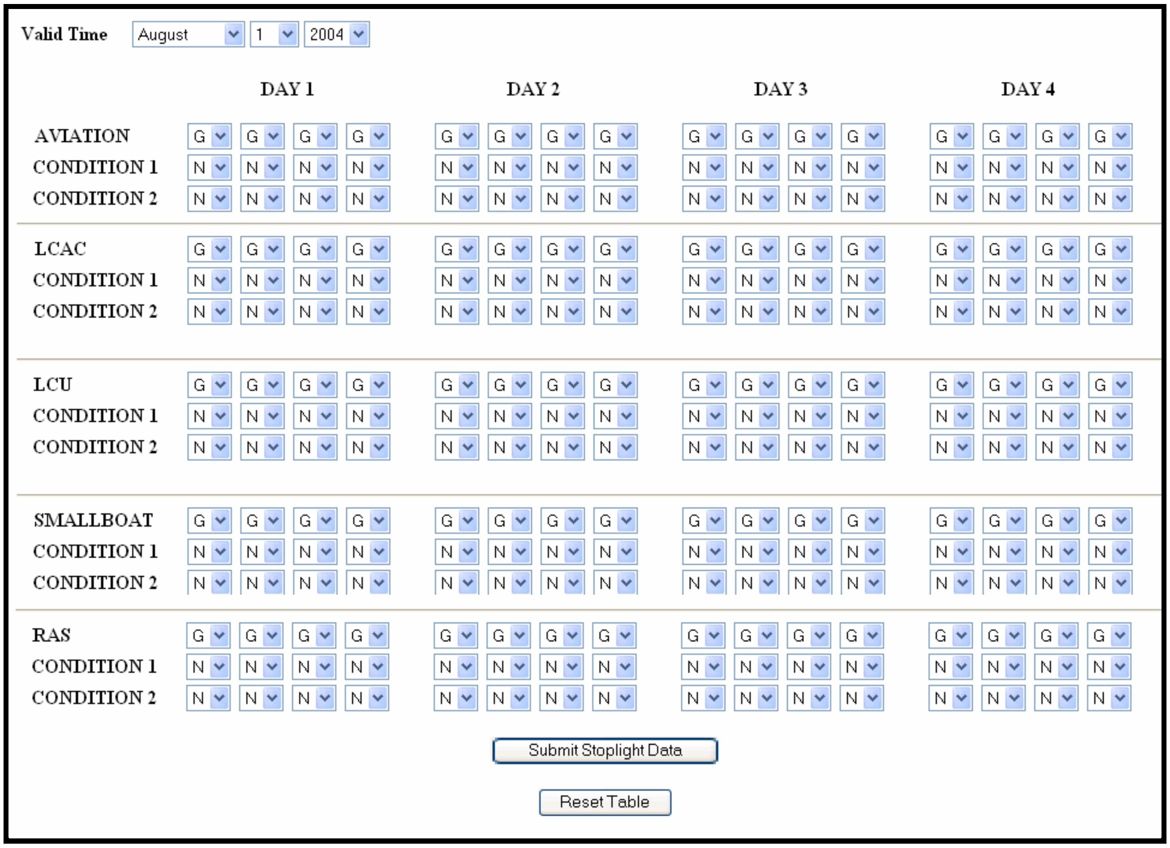


Figure 2. NPS METOC Metrics Support Site home page (available at http://wx.met.nps.navy.mil/~mdbutler/index.html).



Valid Time August 1 2004

	DAY 1				DAY 2				DAY 3				DAY 4			
AVIATION	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
CONDITION 1	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
CONDITION 2	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
LCAC	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
CONDITION 1	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
CONDITION 2	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
LCU	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
CONDITION 1	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
CONDITION 2	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
SMALLBOAT	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
CONDITION 1	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
CONDITION 2	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
RAS	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
CONDITION 1	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
CONDITION 2	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N

Submit Stoplight Data

Reset Table

Figure 3. USS Saipan data collection page (viewable at http://wx.met.nps.navy.mil/~mdbutler/saipan/enter/display_forecast.html).

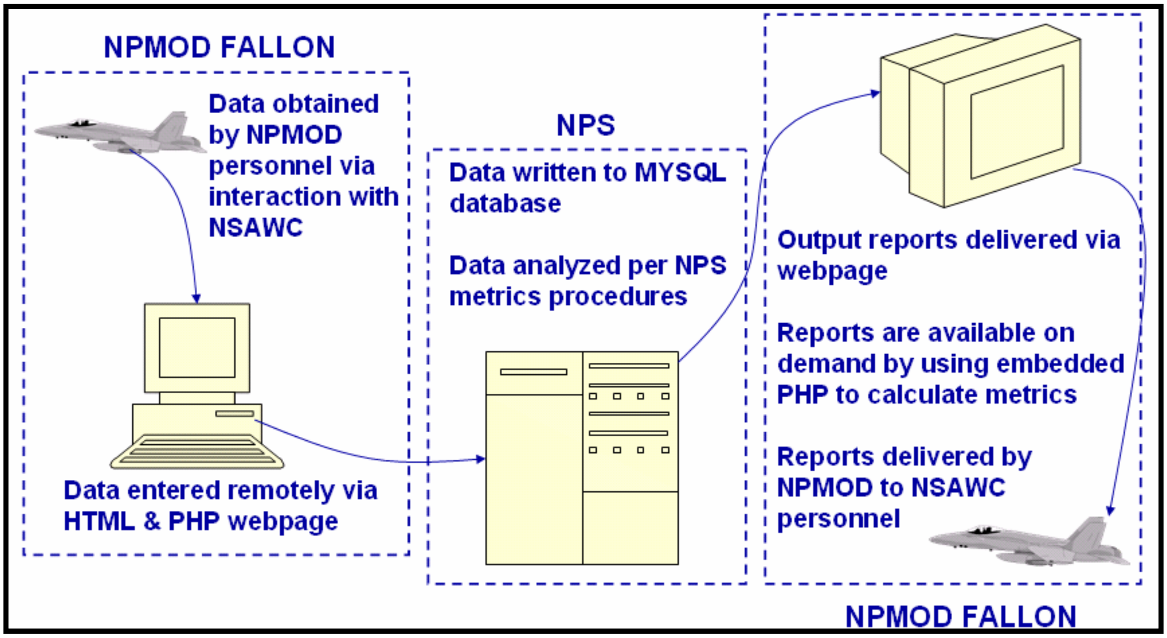


Figure 4. Graphical depiction of the flow of data collected and analyzed for NPMOD Fallon, and of reports issued to NPMOD Fallon.

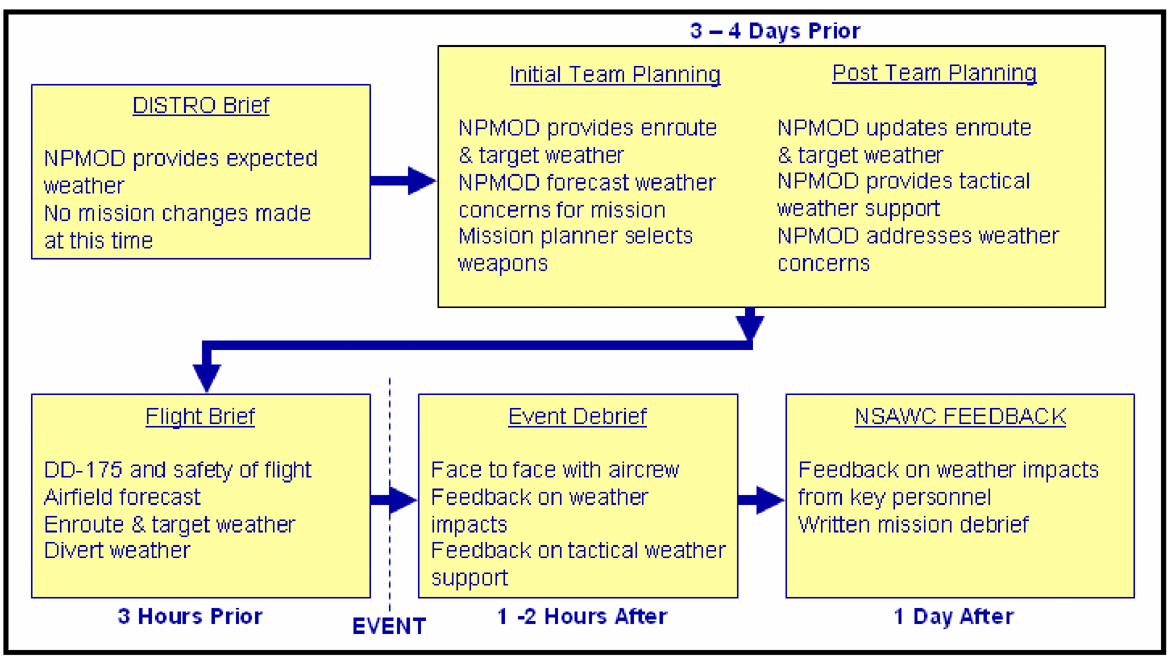


Figure 5. Input from NPMOD Fallon METOC into the NSAWC planning and execution cycle, and from NSAWC to NPMOD Fallon after mssion execution.

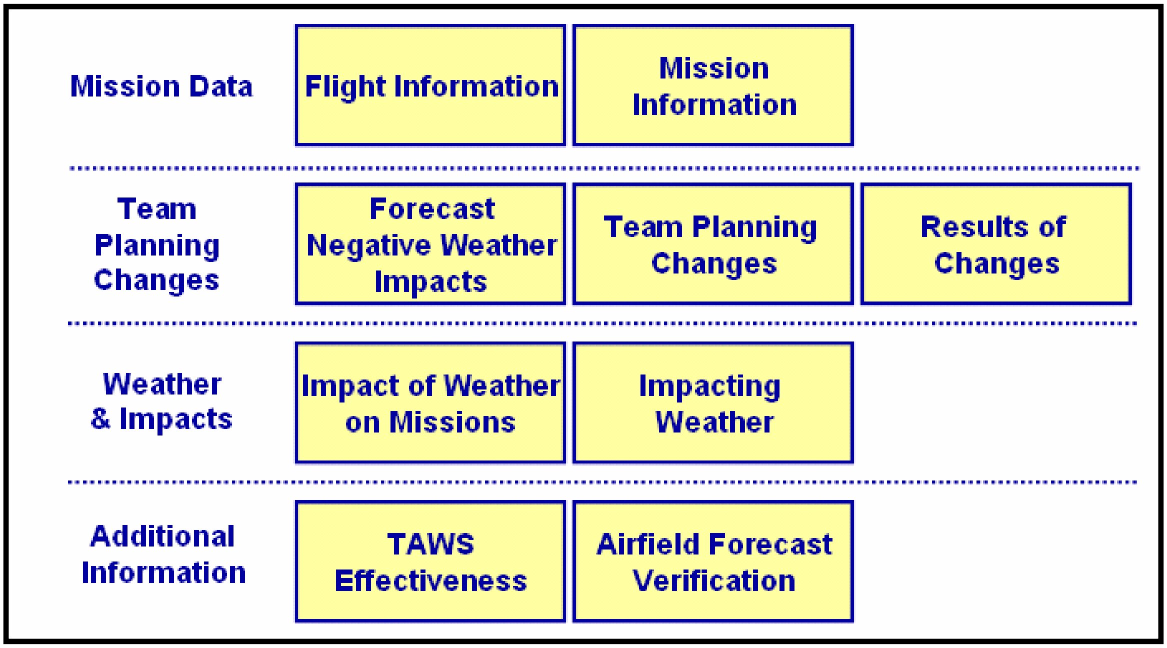


Figure 6. Nine main categories of data collected by NPMOD Fallon for analysis of NPMOD Fallon support of NSAWC operations.

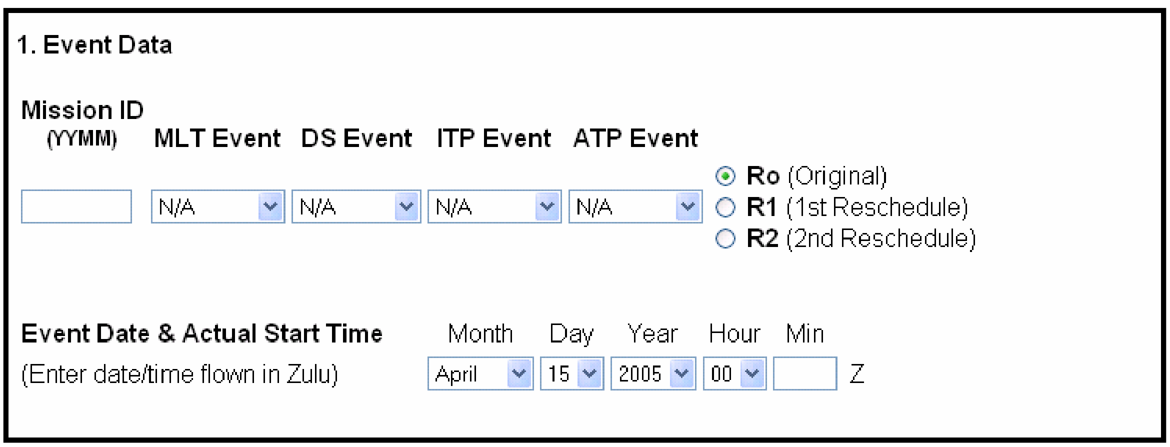


Figure 7. Flight and mission information portion of online collection form.

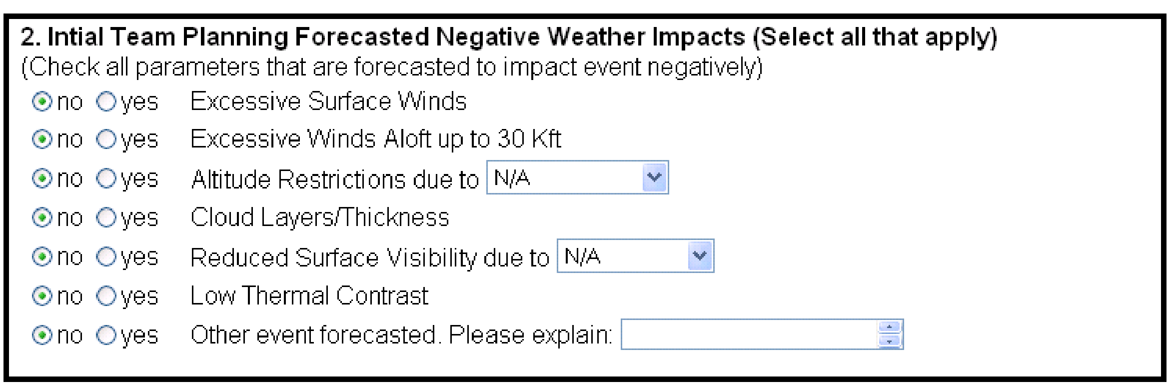
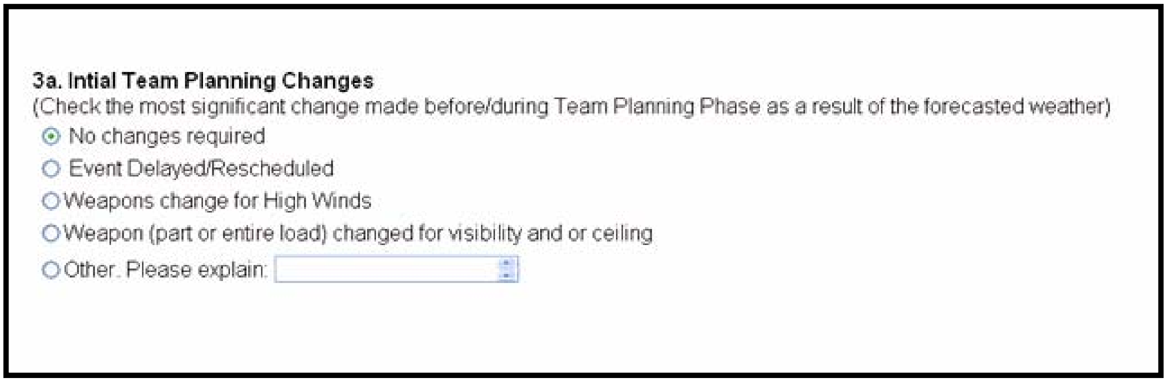
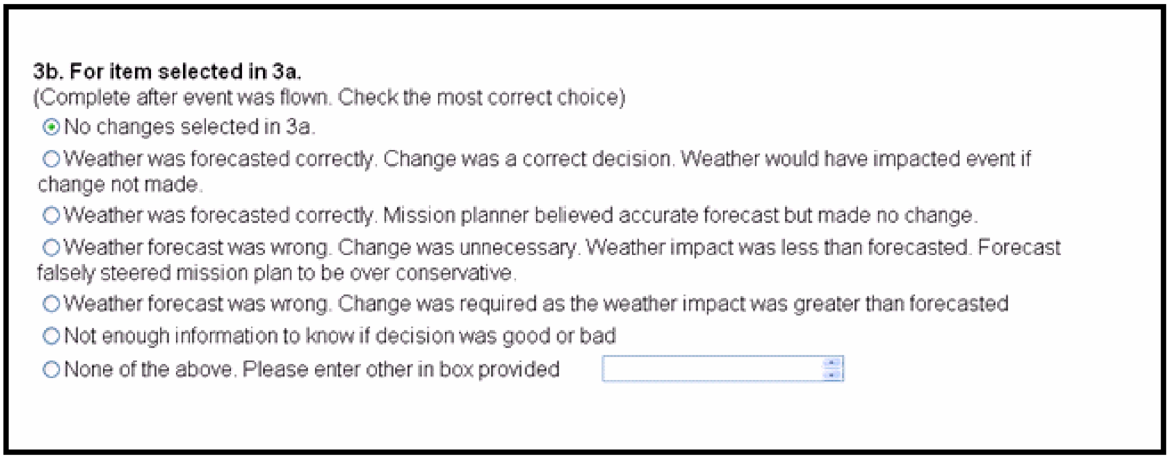


Figure 8. Forecasted negative impacts portion of online collection form.



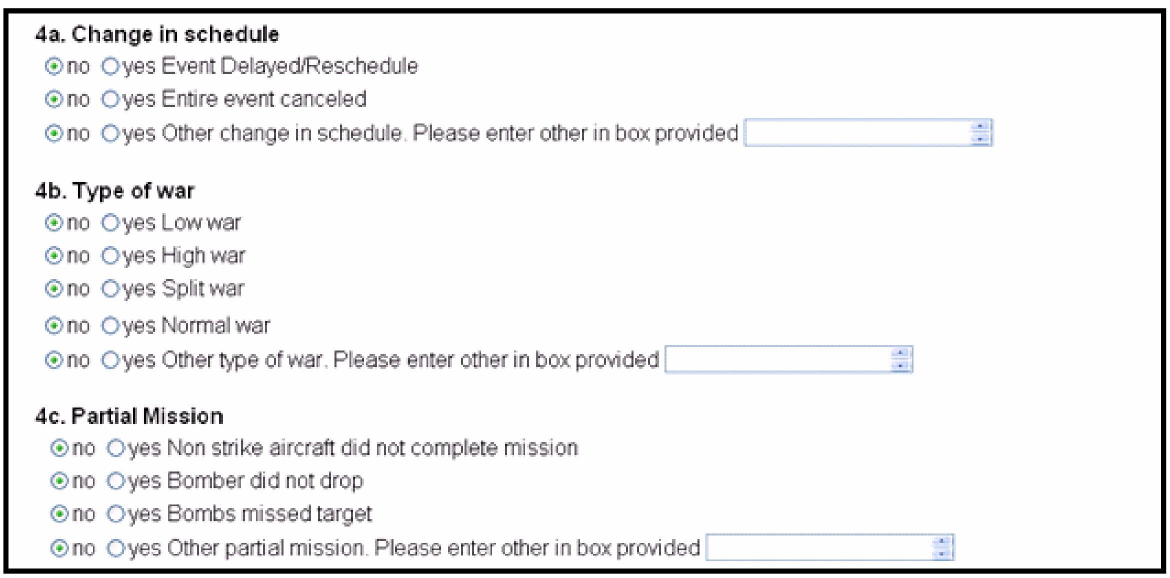
3a. Intial Team Planning Changes
(Check the most significant change made before/during Team Planning Phase as a result of the forecasted weather)
- ◉ No changes required
- ○ Event Delayed/Rescheduled
- ○ Weapons change for High Winds
- ○ Weapon (part or entire load) changed for visibility and or ceiling
- ○ Other. Please explain:

Figure 9. Team planning changes portion of online collection form.



3b. For item selected in 3a.
(Complete after event was flown. Check the most correct choice)
- ◉ No changes selected in 3a.
- ○ Weather was forecasted correctly. Change was a correct decision. Weather would have impacted event if change not made.
- ○ Weather was forecasted correctly. Mission planner believed accurate forecast but made no change.
- ○ Weather forecast was wrong. Change was unnecessary. Weather impact was less than forecasted. Forecast falsely steered mission plan to be over conservative.
- ○ Weather forecast was wrong. Change was required as the weather impact was greater than forecasted
- ○ Not enough information to know if decision was good or bad
- ○ None of the above. Please enter other in box provided

Figure 10. Result form changes to mission portion of online collection form.

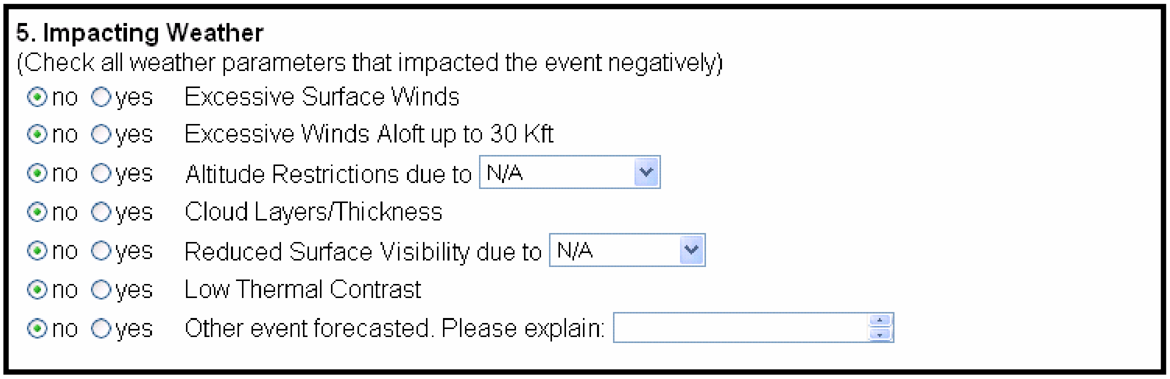


4a. Change in schedule
- ◉ no ○ yes Event Delayed/Reschedule
- ◉ no ○ yes Entire event canceled
- ◉ no ○ yes Other change in schedule. Please enter other in box provided

4b. Type of war
- ◉ no ○ yes Low war
- ◉ no ○ yes High war
- ◉ no ○ yes Split war
- ◉ no ○ yes Normal war
- ◉ no ○ yes Other type of war. Please enter other in box provided

4c. Partial Mission
- ◉ no ○ yes Non strike aircraft did not complete mission
- ◉ no ○ yes Bomber did not drop
- ◉ no ○ yes Bombs missed target
- ◉ no ○ yes Other partial mission. Please enter other in box provided

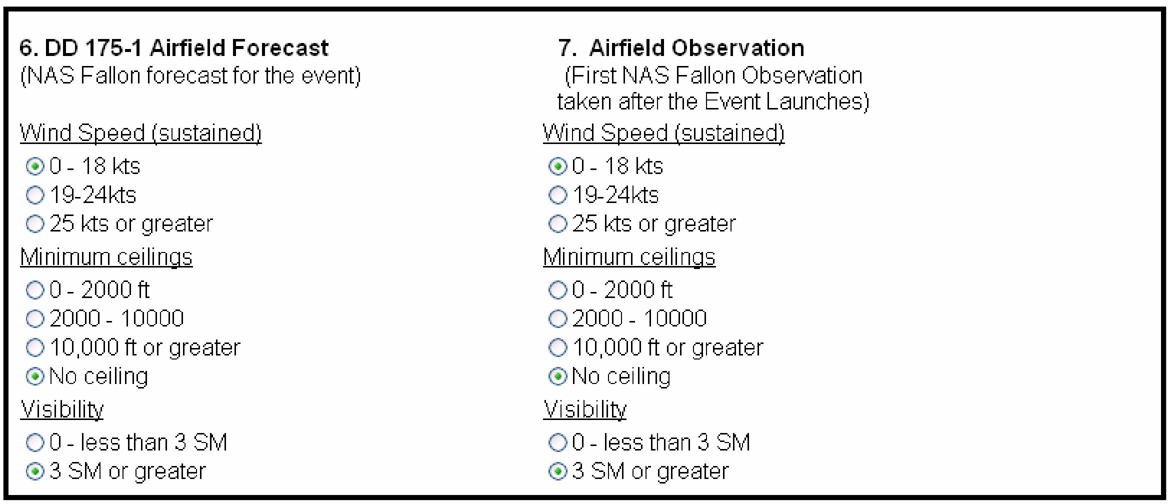
Figure 11. Negative impacts from weather portion of online collection form.



5. Impacting Weather
(Check all weather parameters that impacted the event negatively)

- (•) no ( ) yes Excessive Surface Winds
- (•) no ( ) yes Excessive Winds Aloft up to 30 Kft
- (•) no ( ) yes Altitude Restrictions due to N/A
- (•) no ( ) yes Cloud Layers/Thickness
- (•) no ( ) yes Reduced Surface Visibility due to N/A
- (•) no ( ) yes Low Thermal Contrast
- (•) no ( ) yes Other event forecasted. Please explain:

Figure 12. Negatively impacting weather phenomena portion of the online collection form.



6. DD 175-1 Airfield Forecast
(NAS Fallon forecast for the event)

Wind Speed (sustained)
- (•) 0 - 18 kts
- ( ) 19-24kts
- ( ) 25 kts or greater

Minimum ceilings
- ( ) 0 - 2000 ft
- ( ) 2000 - 10000
- ( ) 10,000 ft or greater
- (•) No ceiling

Visibility
- ( ) 0 - less than 3 SM
- (•) 3 SM or greater

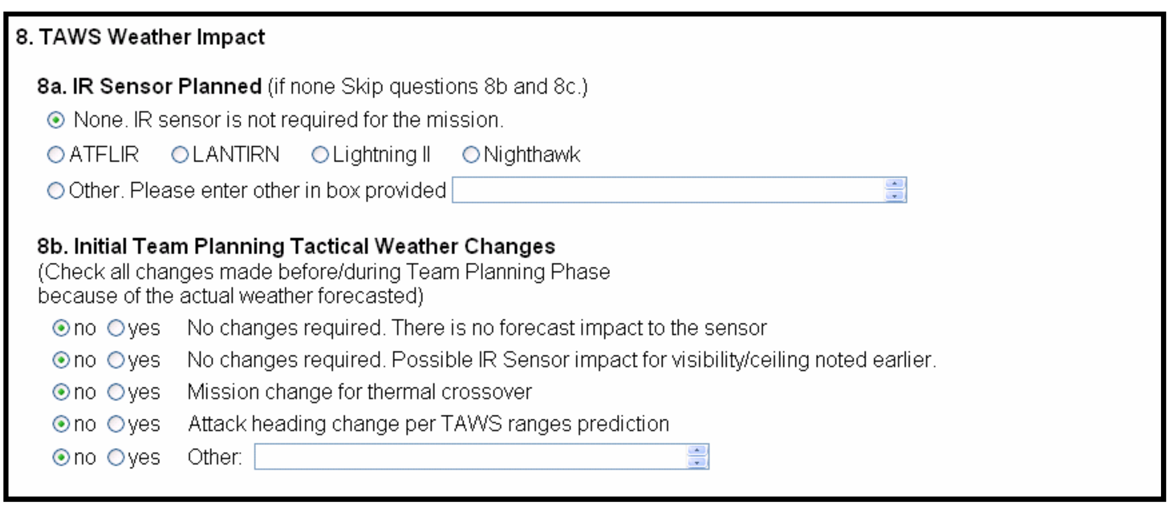
7. Airfield Observation
(First NAS Fallon Observation taken after the Event Launches)

Wind Speed (sustained)
- (•) 0 - 18 kts
- ( ) 19-24kts
- ( ) 25 kts or greater

Minimum ceilings
- ( ) 0 - 2000 ft
- ( ) 2000 - 10000
- ( ) 10,000 ft or greater
- (•) No ceiling

Visibility
- ( ) 0 - less than 3 SM
- (•) 3 SM or greater

Figure 13. Local airfield forecast verification portion of the online collection form.



8. TAWS Weather Impact

8a. IR Sensor Planned (if none Skip questions 8b and 8c.)
- (•) None. IR sensor is not required for the mission.
- ( ) ATFLIR ( ) LANTIRN ( ) Lightning II ( ) Nighthawk
- ( ) Other. Please enter other in box provided

8b. Initial Team Planning Tactical Weather Changes
(Check all changes made before/during Team Planning Phase because of the actual weather forecasted)
- (•) no ( ) yes No changes required. There is no forecast impact to the sensor
- (•) no ( ) yes No changes required. Possible IR Sensor impact for visibility/ceiling noted earlier.
- (•) no ( ) yes Mission change for thermal crossover
- (•) no ( ) yes Attack heading change per TAWS ranges prediction
- (•) no ( ) yes Other:

Figure 14. TAWS effectiveness portion of the online collection form.

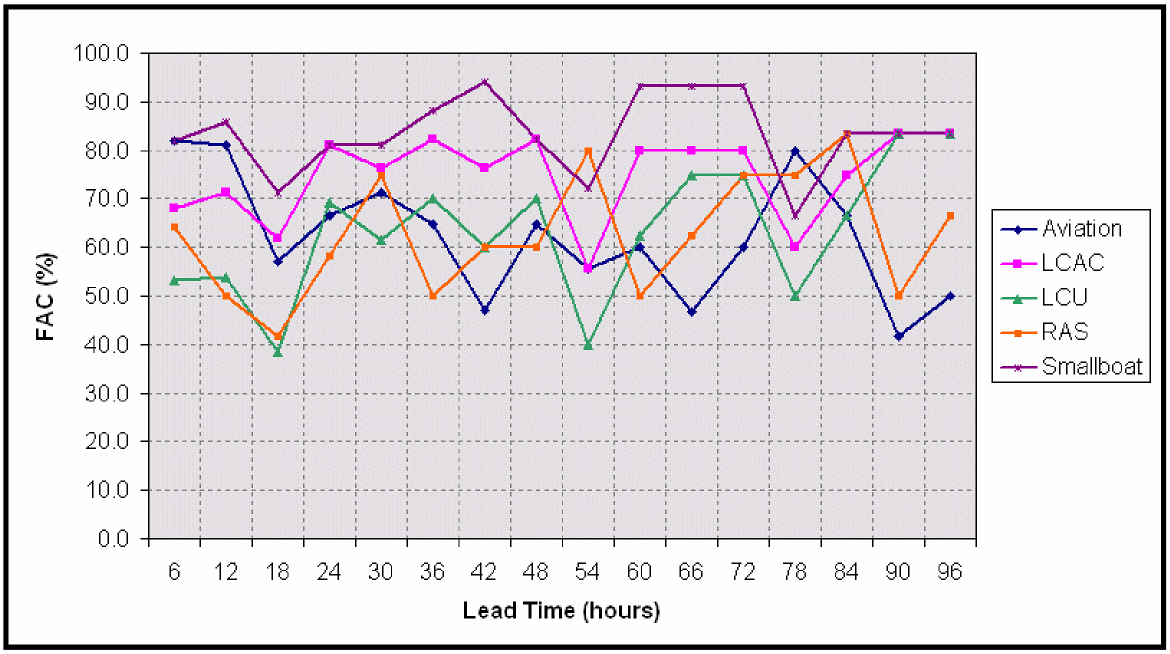


Figure 15. Total Forecast Accuracy (FAC) for five operation types for USS Saipan, September – October 2004.

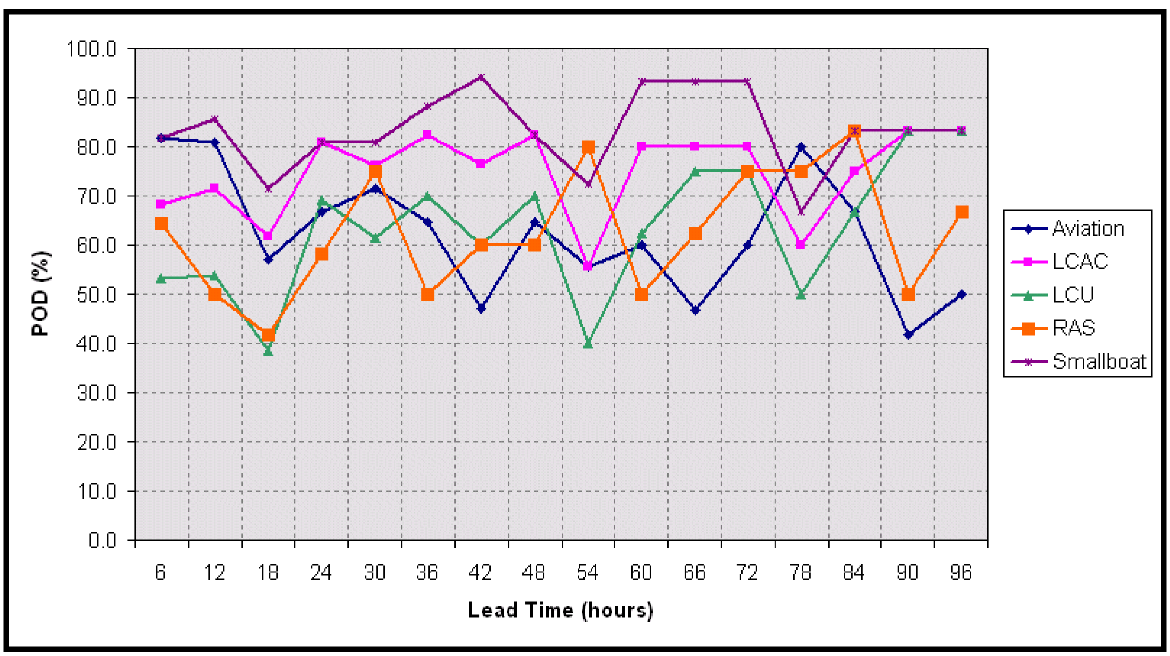


Figure 16. Total Probability of Detection (POD) for five operation types for USS Saipan, September – October 2004.

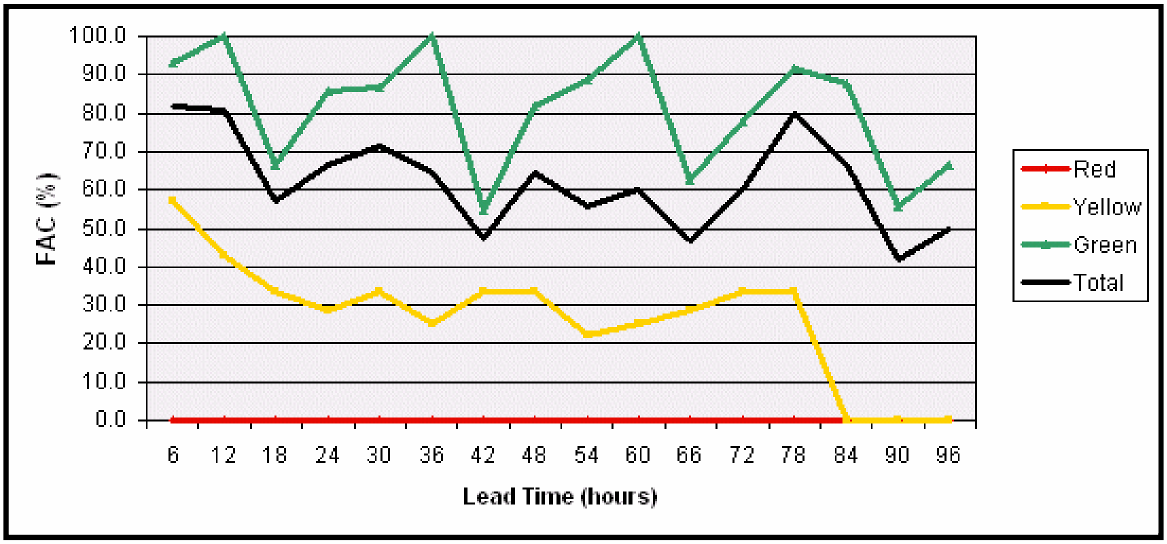


Figure 17. Forecast Accuracy (FAC), USS Saipan, Aviation Forecasts, September – October 2004.

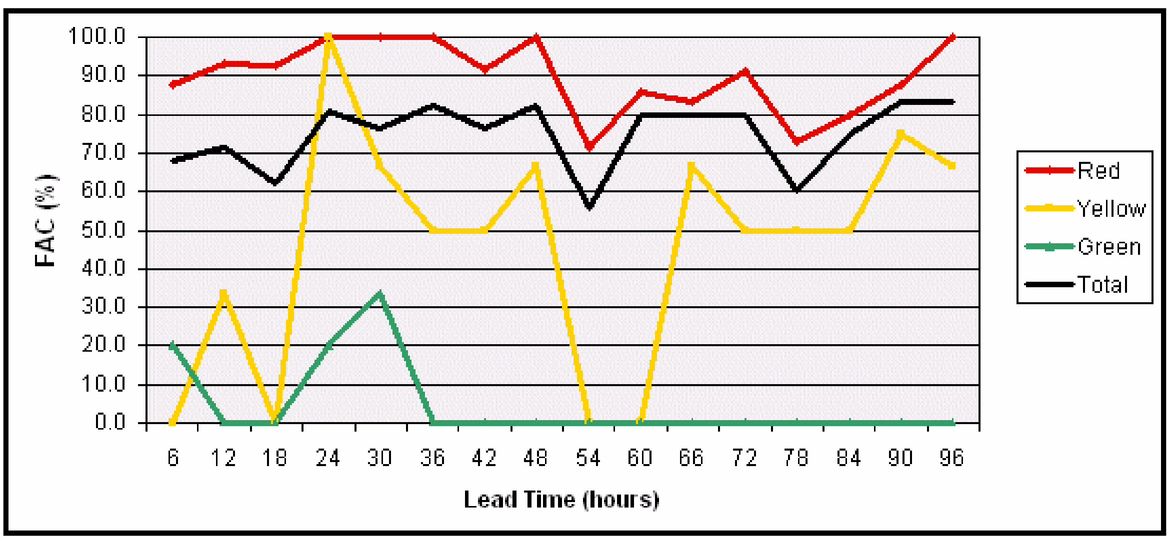


Figure 18. Forecast Accuracy (FAC), USS Saipan, LCAC Forecasts, September – October 2004.

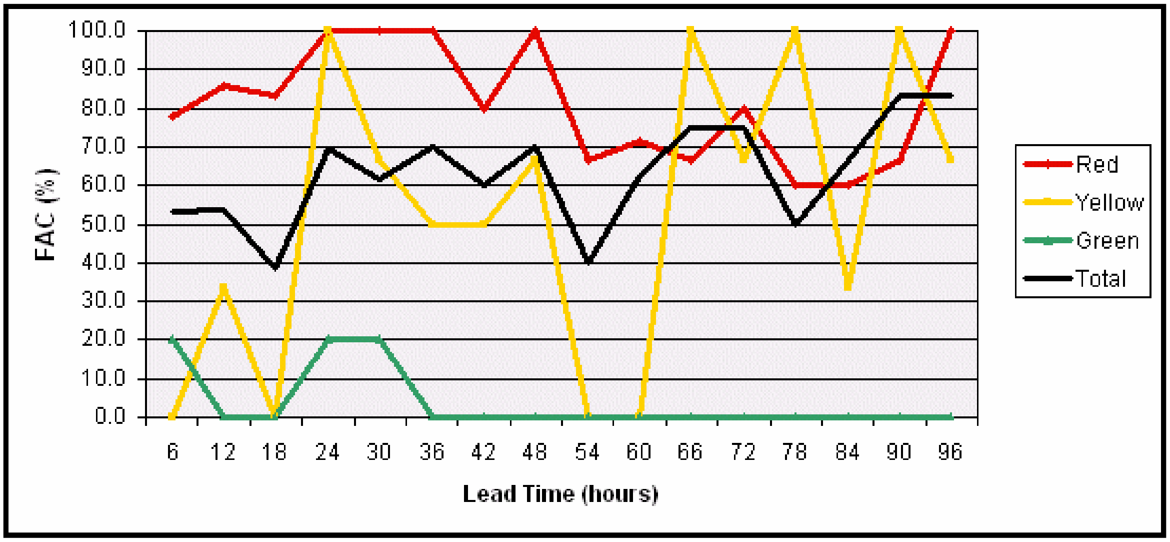


Figure 19. Forecast Accuracy (FAC), USS Saipan, LCU Forecasts, September – October 2004.

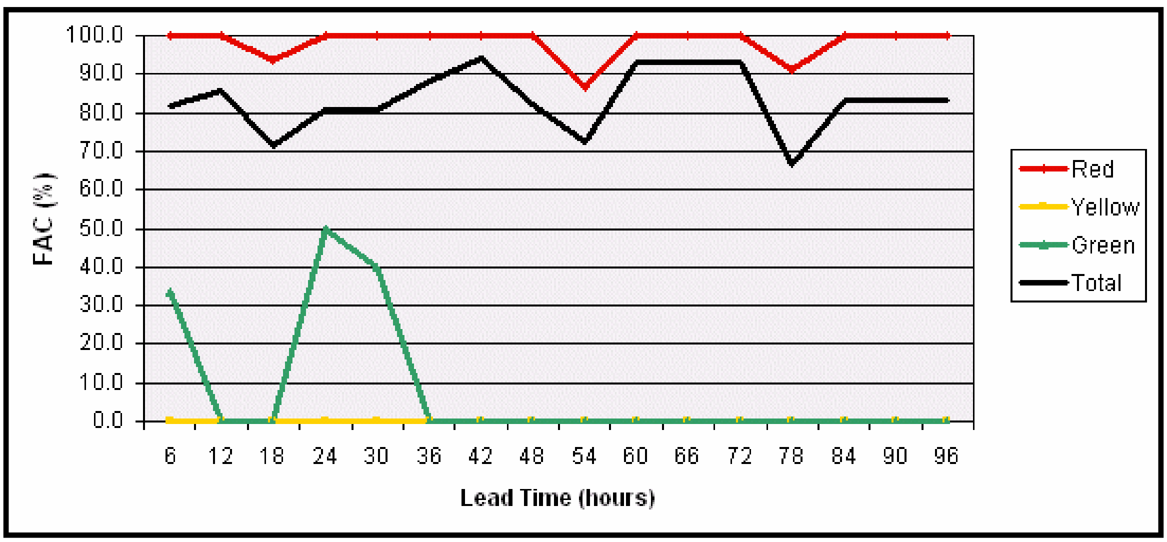


Figure 20. Forecast Accuracy (FAC), USS Saipan, Smallboat Forecasts, September – October 2004.

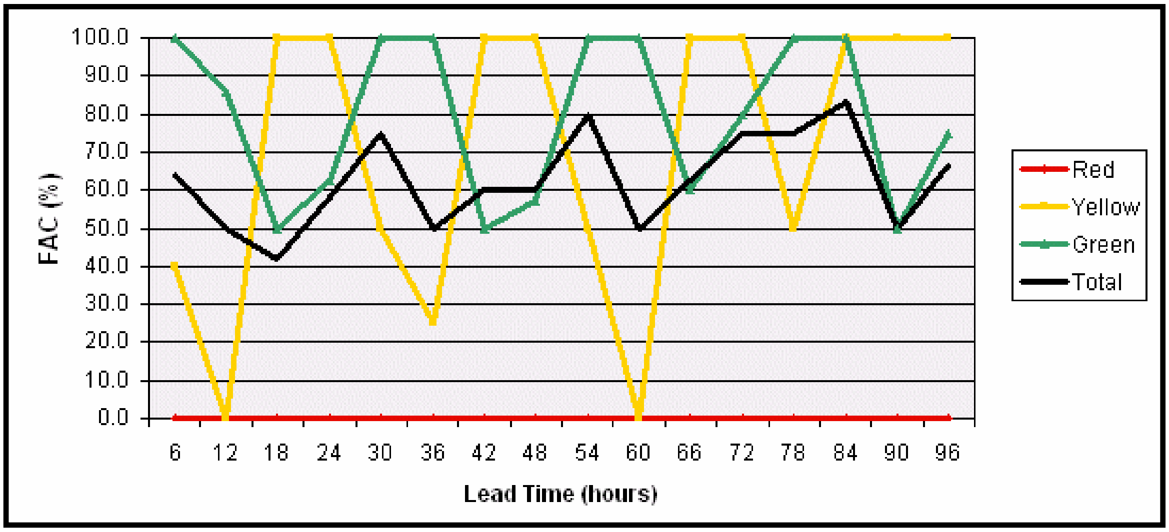


Figure 21. Forecast Accuracy (FAC), USS Saipan, RAS Forecasts, September – October 2004.

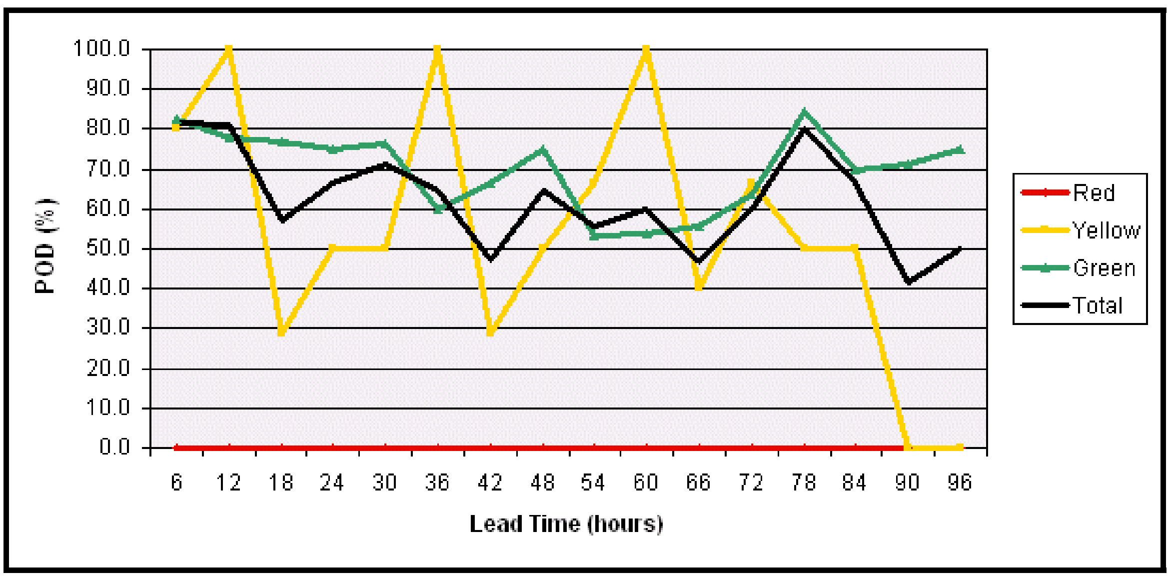


Figure 22. Probability of Detection (POD), USS Saipan, Aviation Forecasts, September – October 2004.

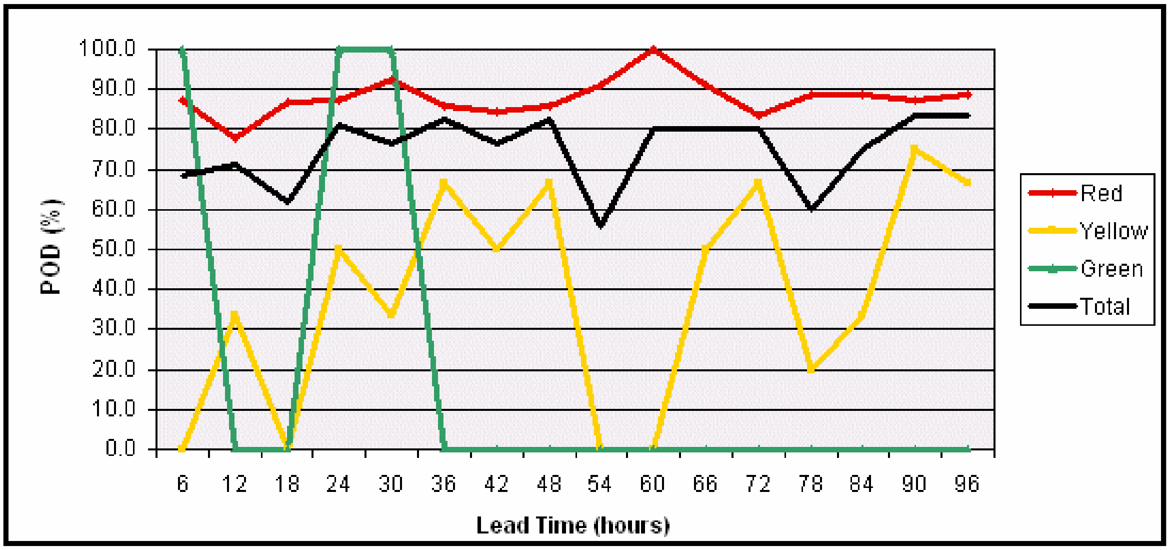


Figure 23. Probability of Detection (POD), USS Saipan, LCAC Forecasts, September – October 2004.

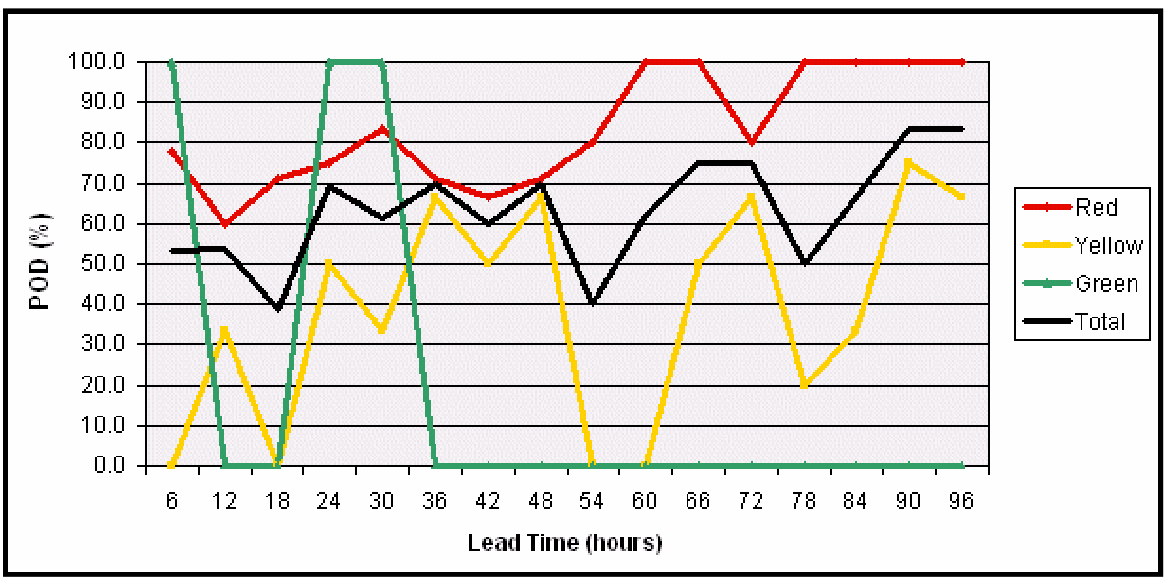


Figure 24. Probability of Detection (POD), USS Saipan, LCU Forecasts, September – October 2004.

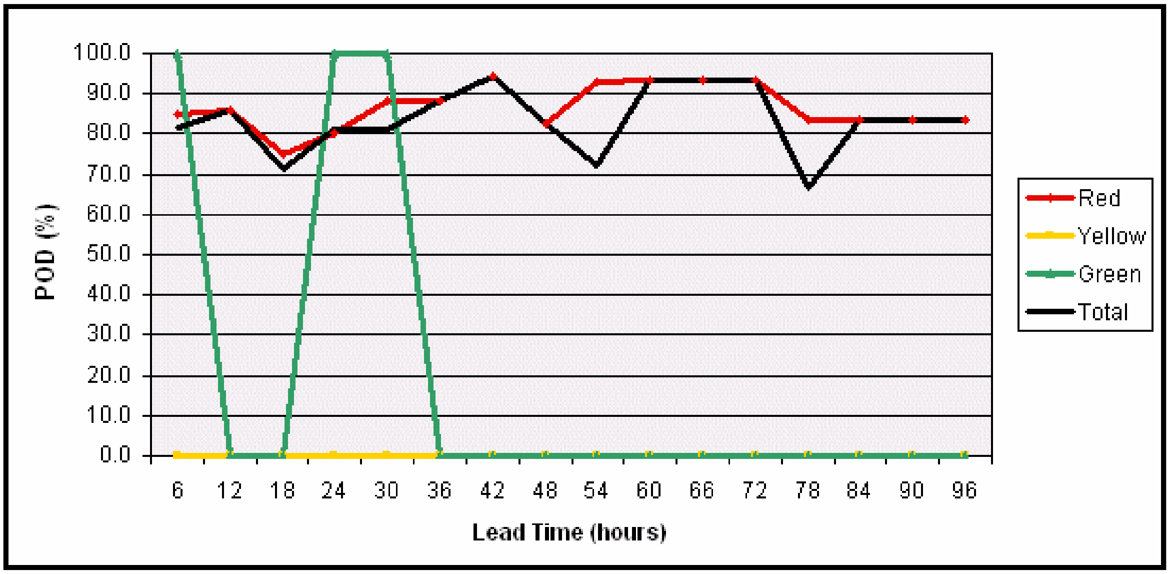


Figure 25. Probability of Detection (POD), USS Saipan, Smallboat Forecasts, September – October 2004.

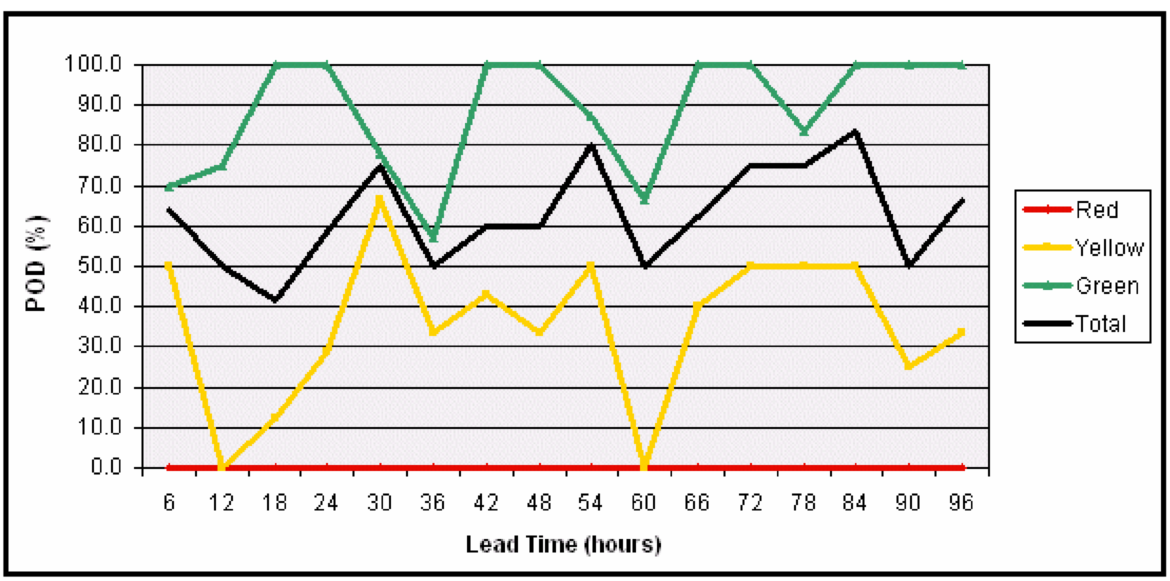


Figure 26. Probability of Detection (POD), USS Saipan, RAS Forecasts, September – October 2004.

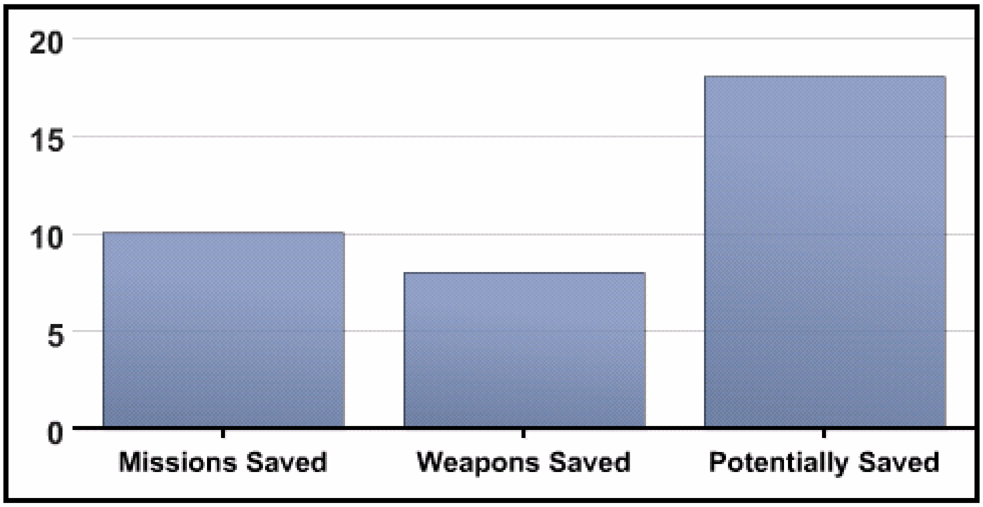


Figure 27. Percent of missions and weapons that were saved or potentially saved as the result of METOC support to NSAWC.

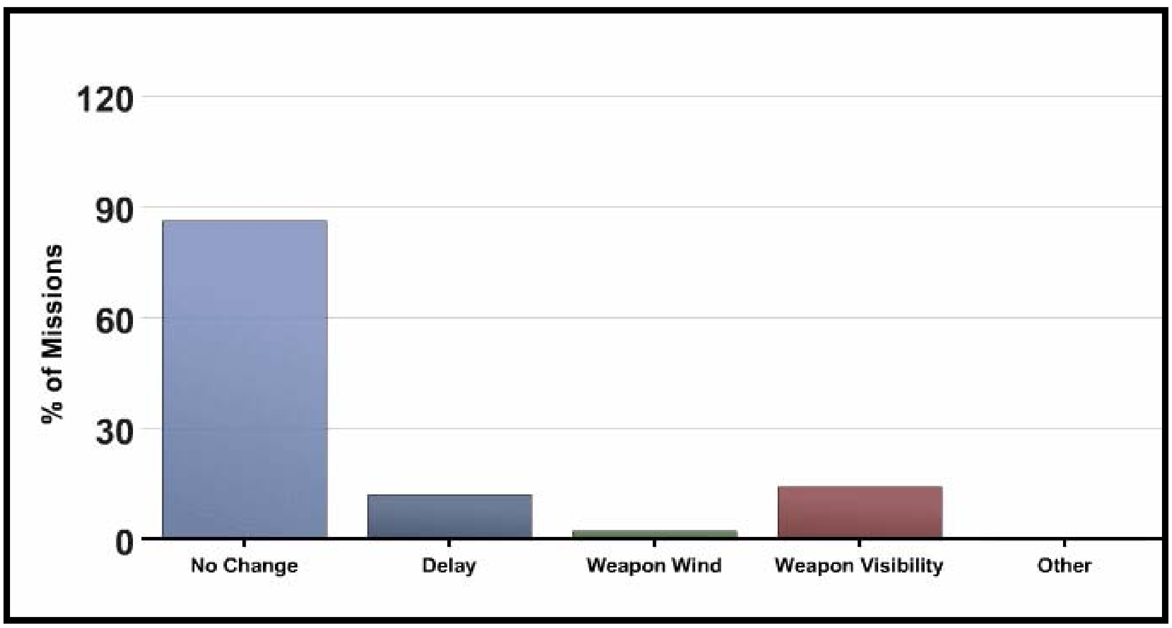


Figure 28. NSAWC mission changes made during initial team planning in response to weather forecasts.

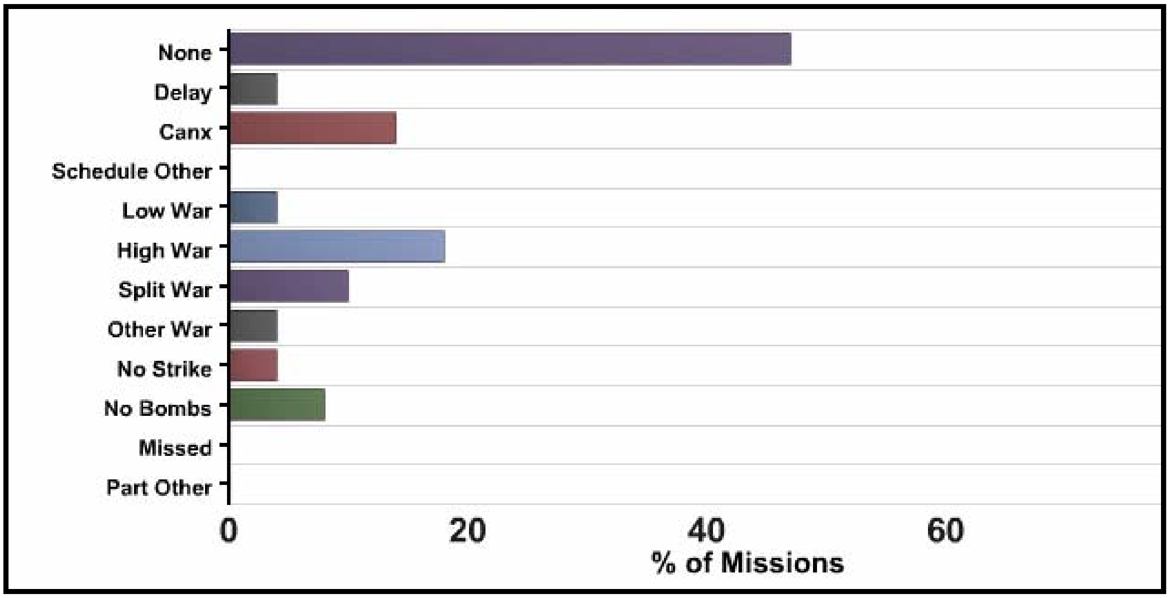


Figure 29. Tactical changes made to NSAWC missions in response to weather observed immediately prior to mission takeoff.

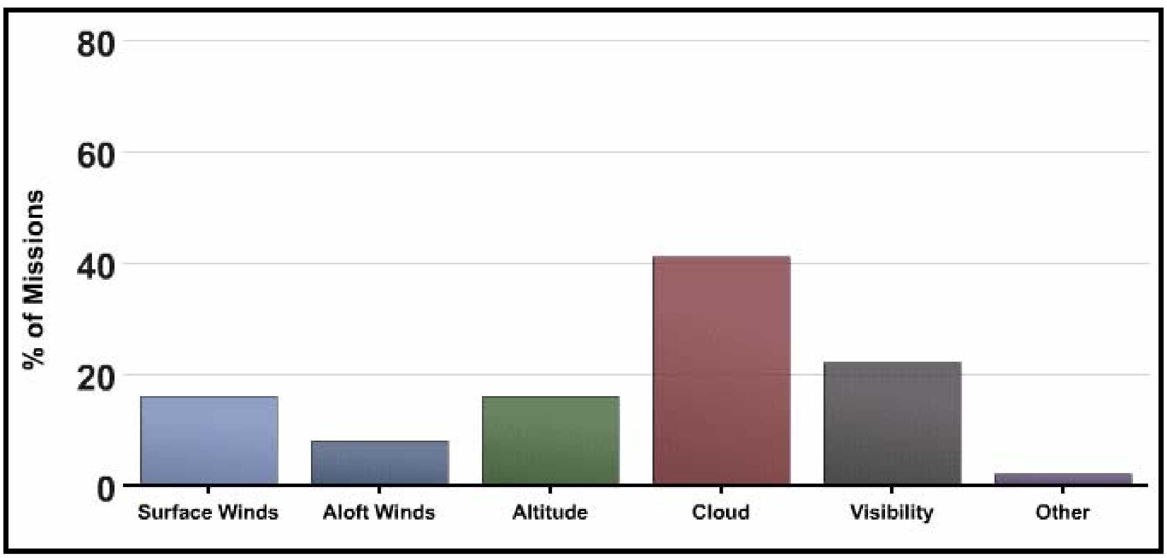


Figure 30. Percent of missions conducted by NSAWC forecasted to be negatively impacted by specific weather phenomena.

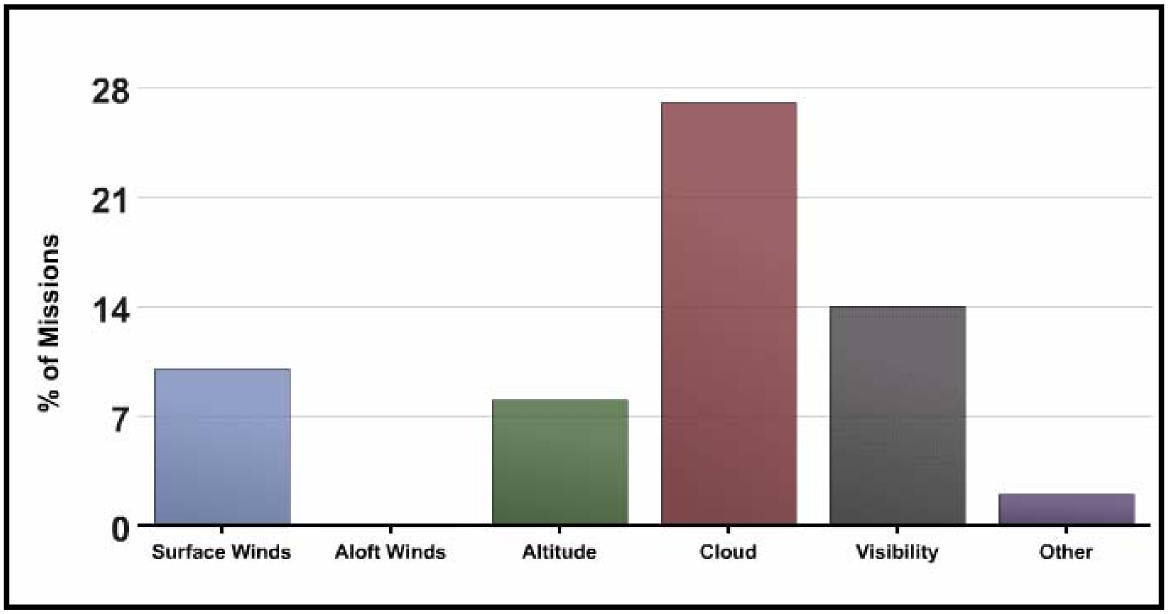
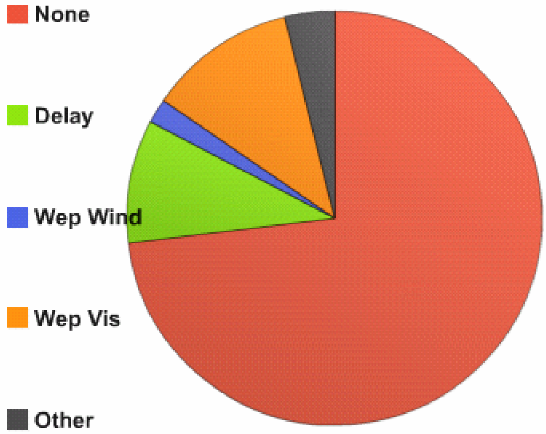


Figure 31. Percent of missions conducted by NSAWC that were negatively impacted by specific weather phenomena.

1. EVENTS IN THIS STUDY	52	
2. EVENTS IMPACTED BY WEATHER	27	
3. PERCENT OF EVENTS IMPACTED BY WEATHER	52	
4. IMPACT BY WEATHER TYPE		
Excessive Surface Wind	7	22 %
Excessive Winds Aloft	0	0 %
Altitude Restrictions	4	13 %
Cloud Thickness/Layers	13	41 %
Reduced Visibility due to Dust	1	3%
Reduced Visibility to Fog	0	0%
Reduced Visibility due to Other	7	22%
5. INITIAL TEAM PLANNING CHANGES		
No changes required	38	73 %
Event Delayed/Rescheduled	5	10 %
Weapons change for High Winds	1	2 %
Weapon changed for visibility and or ceiling	6	12 %
Other	2	4%



6. FORECASTER ACCURACY		
No changes were required during team planning.	29	58 %
Weather was forecasted correctly. Change was correct decision	10	20 %
Weather was forecasted correctly. Mission planner believed accurate forecast but made no change	9	18 %
Weather forecast was wrong. Change was unnecessary. Forecast falsely steered mission plan to be over conservative.	0	0 %
Weather forecast was wrong. Change was required as the weather impact was greater than forecasted	0	0%
Not enough information to know if decision was good or bad.	1	2%
Other	1	2%

Figure 32. Example of NPMOD Fallon on-demand output report generated by using a PHP program embedded into NPS METOC Metrics Support Site web page.

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APPENDIX B: CODE FOR OUTPUT REPORT FOR NPMOD FALLON

The code that was used to create the output report developed for NPMOD, Fallon is listed below. It can also be viewed at the following web link: http://wx.met.nps.navy.mil/~mdbutler/fallon/metrics.htm

```
<!DOCTYPE HTML PUBLIC "-//W3C//DTD HTML 4.01 Transitional//EN"
    "http://www.w3.org/TR/html4/loose.dtd">
<!-- PROGRAM TITLE:  airwing_report_graph.php    -->
<!-- Created June 19, 2005 by LCDR Mark Butler   -->
<!-- Naval Post-Graduate School, Monterey, CA    -->
<!-- Program called from airwing_selection.php   -->
<!-- Data needed:  $airwing_id                   -->
<!-- Requires connection to database "fallon"    -->
<!-- Programs needed:   1) charts.php            -->
<!--                    2) charts.swf            -->
<!--                    3) report_negimpact.php  -->
<!--                    4) report_change.php     -->
<!--                    5) results_impact.php    -->

<HTML>
<HEAD>
      <TITLE>NPMOD FALLON METRICS OUTPUT REPORT</TITLE>
</HEAD>
<BODY>
<!--BANNER AND NAVIGATION LINKS-->

<table border="6" bgcolor="#003366"  cellpadding="0" cellspacing="0"
style="border-collapse:    collapse"    width="100%"    id="AutoNumber1"
height="72">
  <tr>
    <td width="20%" bordercolor="#003366"><img border="0" src="nps.bmp"
></td>
    <td      width="60%"      bordercolor="#003366"><p      align="center"
style="margin-top:
     0; margin-bottom: 0">
    <font color="#FFFF00" size="14" face="Arial">
    <strong>Strike Data Results </strong></font></td>
    <td      width="20%"      bordercolor="#003366"><img      border="0"
src="fallon_blue.bmp" ></td>
  </tr>
</table>
<table border="3" bgcolor="#003366"  cellpadding="0" cellspacing="0"
style="border-collapse:    collapse"    width="100%"    id="AutoNumber1"
align="center">
  <tr>
    <td width="10%" bordercolor="#003366"></td>
    <td  bordercolor="#003366" align="center">
    <a href="http://wx.met.nps.navy.mil/~mdbutler/index.html"
```

```
     STYLE="text-decoration: none"><FONT COLOR="#FFFF00"
     onMouseOver="this.style.color = '#FFFFFF'"
     onMouseOut="this.style.color   =   '#FFFF00'"><font      size="2"
face="Arial">
     Metrics Home </font></a>
    </td>
    <td  bordercolor="#003366" align="center">
    <a href="http://wx.met.nps.navy.mil/~mdbutler/fallon/metrics.htm"
     STYLE="text-decoration: none"><FONT COLOR="#FFFF00"
      onMouseOver="this.style.color = '#FFFFFF'"
      onMouseOut="this.style.color    =    '#FFFF00'"><font    size="2"
face="Arial">
     NSAWC Home </font></a>
    </td>
    <td  bordercolor="#003366" align="center">
    <a
href="http://wx.met.nps.navy.mil/~mdbutler/fallon/enter/main.html"
     STYLE="text-decoration: none"><FONT COLOR="#FFFF00"
      onMouseOver="this.style.color = '#FFFFFF'"
      onMouseOut="this.style.color    =    '#FFFF00'"><font    size="2"
face="Arial">
     NSAWC Enter</font></a>
    </td>
    <td  bordercolor="#003366" align="center">
    <a
href="http://wx.met.nps.navy.mil/~mdbutler/fallon/delete/delete.php"
     STYLE="text-decoration: none"><FONT COLOR="#FFFF00"
      onMouseOver="this.style.color = '#FFFFFF'"
      onMouseOut="this.style.color    =    '#FFFF00'"><font    size="2"
face="Arial">
     NSAWC Delete</font></a>
    </td>
        <td  bordercolor="#003366" align="center">
    <a
href="http://wx.met.nps.navy.mil/~mdbutler/fallon/review/review.php"
     STYLE="text-decoration: none"><FONT COLOR="#FFFF00"
      onMouseOver="this.style.color = '#FFFFFF'"
      onMouseOut="this.style.color    =    '#FFFF00'"><font    size="2"
face="Arial">
     NSAWC Review</font></a>
    </td>
     <td  bordercolor="#003366" align="center">
    <a
href="http://wx.met.nps.navy.mil/~mdbutler/fallon/results/airwing_selec
tion.php"
     STYLE="text-decoration: none"><FONT COLOR="#FFFF00"
      onMouseOver="this.style.color = '#FFFFFF'"
      onMouseOut="this.style.color    =    '#FFFF00'"><font    size="2"
face="Arial">
     NSAWC Results</font></a>
    </td>
    <td  bordercolor="#003366" align="center">
    <a href="http://wx.met.nps.navy.mil/~mdbutler/help/help.html"
     STYLE="text-decoration: none"><FONT COLOR="#FFFF00"
      onMouseOver="this.style.color = '#FFFFFF'"
      onMouseOut="this.style.color    =    '#FFFF00'"><font    size="2"
face="Arial">
```

```
     About Metrics</font></a>
    </td>
    <td width="10%" bordercolor="#003366"></td>

  </tr>
</table>
<?php
//
//  IMPORT $airwing_id from airwing_selection.php
//
$airwing_id=$_POST['airwing_id'];
//
//CONNECT TO DATABASE
//
$host="localhost";
$user="root";
$password="";
$database="fallon";

$connection = mysql_connect($host,$user,$password)
       or die ("couldn't connect to server");
$db = mysql_select_db($database,$connection)
       or die ("Couldn't select database");

/*----------------------------------------------------------
CHECK TO SEE IF AIRWING IS SPECFIC AIRWING OR ALL AIRWINGS
AND DEFINE SQL QUERY TO BE USED TO RETRIVE DATA
---------------------------------------------------------*/
if ($airwing_id=="ALL") {
   $query                           =                          "SELECT
mission_id,itp_delayed,itp_canceled,itp_schedule_other,

itp_lowwar,itp_highwar,itp_splitwar,itp_war_other,itp_partial_nostrike,
   itp_partial_nobombs,itp_partial_missed,itp_partial_other,

mission_surface_winds,mission_aloft_winds,mission_altitude,mission_clou
ds,
   mission_visibility,mission_other,mission_visibility_phenomena,
   mission_altitude_phenomena,mission_thermal,
   changed,change_verif,
   air_forecast_wind,air_observe_wind,air_forecast_ceiling,
   air_observe_ceiling,air_forecast_visibility,air_observe_visibility,
   ir_sensor,ir_out_acc,ir_out_20plus,ir_out_20less,
   ir_plan_none,ir_plan_poss,ir_plan_thermal,ir_plan_taws,ir_plan_other
   FROM strikedata";
} else {
   $query                           =                          "SELECT
mission_id,itp_delayed,itp_canceled,itp_schedule_other,

itp_lowwar,itp_highwar,itp_splitwar,itp_war_other,itp_partial_nostrike,
   itp_partial_nobombs,itp_partial_missed,itp_partial_other,

mission_surface_winds,mission_aloft_winds,mission_altitude,mission_clou
ds,
   mission_visibility,mission_other,mission_visibility_phenomena,
   mission_altitude_phenomena,mission_thermal,
   changed,change_verif,
```

```
   air_forecast_wind,air_observe_wind,air_forecast_ceiling,
   air_observe_ceiling,air_forecast_visibility,air_observe_visibility,
   ir_sensor,ir_out_acc,ir_out_20plus,ir_out_20less,
   ir_plan_none,ir_plan_poss,ir_plan_thermal,ir_plan_taws,ir_plan_other
   FROM strikedata WHERE airwing_id=$airwing_id";
}
  $result = mysql_query($query)
       or die ("Couldn't execute query.");
//
//INTIALIZE COUNTERS TO BE USED TO DETERMINE METRICS
//
$mission_counter=0;
$impact_yes=0;
$none=0;
$delay_impact=0;
$canx=0;
$sched_other=0;
$lowwar=0;
$highwar=0;
$splitwar=0;
$war_other=0;
$partial_nostrike=0;
$partial_nobombs=0;
$partial_other=0;
$partial_missed=0;

$surf_wind=0;
$aloft_wind=0;
$alt=0;
$vis=0;
$vis_pr=0;
$vis_ds=0;
$vis_haze=0;
$vis_fog=0;
$vis_na=0;
$cloud=0;
$therm=0;
$other_impact=0;

$none_changed=0;
$delay=0;
$wep_wind=0;
$wep_vis=0;
$other_changed=0;

$no3a=0;
$correct=0;
$nochange=0;
$wrong_unnec=0;
$wrong_nec=0;
$unknown=0;
$other_verf=0;

$wind_correct=0;
$wind_greater=0;
$wind_less=0;
$ceil_correct=0;
```

```
$ceil_greater=0;
$ceil_less=0;
$vis_correct=0;
$vis_greater=0;
$vis_less=0;

$atflir_acc=0;
$atflir_plus=0;
$atflir_less=0;
$lantirn_acc=0;
$lantirn_plus=0;
$lantirn_less=0;
$nighthawk_acc=0;
$nighthawk_plus=0;
$nighthawk_less=0;

$ir_none=0;
$ir_poss=0;
$ir_thermal=0;
$ir_taws=0;
$ir_other=0;
//
// EXECUTION OF WHILE LOOP TO RETRIVE DATA AND TO PERFORM METRIC
ANALYSIS
//
while ($row = mysql_fetch_array($result))
  {
     extract($row);
     //
     //MISSION COUNTER
     //
     $mission_counter=$mission_counter+1;
     /*------------------------------------------
     WEATHER WHICH RESULTED IN IMPACTS IS ANALYZED
     1)DATA IS ASSIGNED TO VARIABLES FROM QUERY
     2)VARIABLES ARE THEN CHECK TO SEE WHICH WEATHER
       PHENOMENA CAUSED AN IMPACT
     -------------------------------------------*/
     $mission_surface_winds=$row['mission_surface_winds'];
     $mission_aloft_winds=$row['mission_aloft_winds'];
     $mission_altitude=$row['mission_altitude'];
     $mission_clouds=$row['mission_clouds'];
     $mission_visibility=$row['mission_visibility'];
     $mission_other=$row['mission_other'];

$mission_visibility_phenomena=$row['mission_visibility_phenomena'];
     $mission_altitude_phenomena=$row['mission_altitude_phenomena'];
     $mission_thermal=$row['mission_thermal'];
     if ($mission_surface_winds=="yes") {
     $surf_wind=$surf_wind+1;
     }
     if ($mission_aloft_winds=="yes") {
     $aloft_wind=$aloft_wind+1;
     }
     if ($mission_altitude=="yes") {
     $alt=$alt+1;
     }
```

```
if ($mission_clouds=="yes") {
$cloud=$cloud+1;
}
if ($mission_visibility=="yes") {
     $vis=$vis+1;
            if ($mission_visibility_phenomena=="na") {
            $vis_na=$vis_na+1;
            }
            if ($mission_visibility_phenomena=="fog") {
            $vis_fog=$vis_fog+1;
            }
            if ($mission_visibility_phenomena=="haze") {
            $vis_haze=$vis_haze+1;
            }
            if ($mission_visibility_phenomena=="duststorm") {
            $vis_ds=$vis_ds+1;
            }
            if ($mission_visibility_phenomena=="precip") {
            $vis_pr=$vis_pr+1;
            }
}
if ($mission_thermal=="yes") {
$therm=$therm+1;
}
if ($mission_other=="yes") {
$other_impact=$other_impact+1;
}
//
//ANALYZE INITIAL TEAM PLANNING CHANGES
//
$changed=$row['changed'];
switch ($changed) {
  case "none":
      $none_changed=$none_changed+1;
  break;
  case "delayed":
      $delay=$delay+1;
  break;
  case "weaponwind":
      $wep_wind=$wep_wind+1;
  break;
  case "weaponvis":
      $wep_vis=$wep_vis+1;
  break;
  case "other":
      $other_changed=$other_changed+1;
  break;
}
//
//ANALYZE FORECAST ACCURACY
//
switch ($change_verif) {
  case "no3a" :
  $no3a=$no3a+1;
  break;
  case "correct" :
  $correct=$correct+1;
```

```
        break;
        case "nochange" :
        $nochange=$nochange+1;
        break;
        case "wrong_unnec" :
        $wrong_unnec=$wrong_unnec+1;
        break;
        case "wrong_nec" :
        $wrong_nec=$wrong_nec+1;
        break;
        case "unknown" :
        $unknown=$unknown+1;
        break;
        case "other" :
        $other_verf=$other_verf+1;
        break;
      }
      //
      //ANALYZE IMPACTS RESULTING FROM WEATHER
      //
      $itp_delayed=$row['itp_delayed'];
      $itp_canceled=$row['itp_canceled'];
      $itp_schedule_other=$row['itp_schedule_other'];
      $itp_lowwar=$row['itp_lowwar'];
      $itp_highwar=$row['itp_highwar'];
      $itp_splitwar=$row['itp_splitwar'];
      $itp_war_other=$row['itp_war_other'];
      $itp_partial_nostrike=$row['itp_partial_nostrike'];
      $itp_partial_nobombs=$row['itp_partial_nobombs'];
      $itp_partial_missed=$row['itp_partial_missed'];
      $itp_partial_other=$row['itp_partial_other'];
      if ($itp_delayed=="no" and $itp_canceled=="no" and
$itp_schedule_other=="no"
       and $itp_lowwar=="no" and $itp_highwar=="no" and
$itp_splitwar=="no"
       and $itp_war_other=="no" and $itp_partial_nostrike=="no" and
$itp_partial_nobombs=="no"
       and $itp_partial_other=="no" and $itp_partial_missed=="no" ) {
      $none=$none+1;
      }
      if ($itp_delayed=="yes" or $itp_canceled=="yes" or
$itp_schedule_other=="yes"
       or $itp_lowwar=="yes" or $itp_highwar=="yes" or
$itp_splitwar=="yes"
       or $itp_war_other=="yes" or $itp_partial_nostrike=="yes" or
$itp_partial_nobombs=="yes"
       or $itp_partial_other=="yes" or $itp_partial_missed=="yes" ) {
      $impact_yes=$impact_yes+1;
      }
      if ($itp_delayed=="yes") {
      $delay_impact=$delay_impact+1;
      }
      if ($itp_canceled=="yes") {
      $canx=$canx+1;
      }
      if ($itp_schedule_other=="yes") {
      $sched_other=$sched_other+1;
```

```
}
if ($itp_lowwar=="yes") {
$lowwar=$lowwar+1;
}
if ($itp_highwar=="yes") {
$highwar=$highwar+1;
}
if ($itp_splitwar=="yes") {
$splitwar=$splitwar+1;
}
if ($itp_war_other=="yes") {
$war_other=$war_other+1;
}
if ($itp_partial_nostrike=="yes") {
$partial_nostrike=$partial_nostrike+1;
}
if ($itp_partial_nobombs=="yes") {
$partial_nobombs=$partial_nobombs+1;
}
if ($itp_partial_other=="yes") {
$partial_other=$partial_other+1;
}
if ($itp_partial_missed=="yes") {
$partial_missed=$partial_missed+1;
}
//
//ANALYZE OF FORECAST ACCURACY OF LOCAL AIRFIELD CONDITIONS
//
$air_forecast_wind=$row['air_forecast_wind'];
$air_observe_wind=$row['air_observe_wind'];
$air_forecast_ceiling=$row['air_forecast_ceiling'];
$air_observe_ceiling=$row['air_observe_ceiling'];
$air_forecast_visibility=$row['air_forecast_visibility'];
$air_observe_visibility=$row['air_observe_visibility'];
if ($air_forecast_wind==$air_observe_wind) {
  $wind_correct=$wind_correct+1;
}
if($air_observe_wind=="0-18" and $air_forecast_wind=="19-24" ) {
  $wind_less=$wind_less+1;
}
if($air_observe_wind=="0-18" and $air_forecast_wind=="25" ) {
  $wind_less=$wind_less+1;
}
if($air_observe_wind=="19-24" and $air_forecast_wind=="0-18" ) {
  $wind_greater=$wind_greater+1;
}
if($air_observe_wind=="19-24" and $air_forecast_wind=="25" ) {
  $wind_less=$wind_less+1;
}
if($air_observe_wind=="25" and $air_forecast_wind=="0-18" ) {
  $wind_greater=$wind_greater+1;
}
if($air_observe_wind=="25" and $air_forecast_wind=="19-24" ) {
  $wind_greater=$wind_greater+1;
}

if ($air_forecast_ceiling==$air_observe_ceiling) {
```

```
       $ceil_correct=$ceil_correct+1;
     }
     if($air_observe_ceiling=="0-2000"                              and
$air_forecast_ceiling=="2000-10000" ) {
       $ceil_less=$ceil_less+1;
     }
     if($air_observe_ceiling=="0-2000"                              and
$air_forecast_ceiling=="10000" ) {
       $ceil_less=$ceil_less+1;
     }
     if($air_observe_ceiling=="0-2000"                              and
$air_forecast_ceiling=="noceiling" ) {
       $ceil_less=$ceil_less+1;
     }
     if($air_observe_ceiling=="2000-10000"                          and
$air_forecast_ceiling=="0-2000" ) {
       $ceil_greater=$ceil_greater+1;
     }
     if($air_observe_ceiling=="2000-10000"                          and
$air_forecast_ceiling=="10000" ) {
       $ceil_less=$ceil_less+1;
     }
     if($air_observe_ceiling=="2000-10000"                          and
$air_forecast_ceiling=="noceiling" ) {
       $ceil_less=$ceil_less+1;
     }
     if($air_observe_ceiling=="10000"   and   $air_forecast_ceiling=="0-
2000" ) {
       $ceil_greater=$ceil_greater+1;
     }
     if($air_observe_ceiling=="10000"  and  $air_forecast_ceiling=="2000-
10000" ) {
       $ceil_greater=$ceil_greater+1;
     }
     if($air_observe_ceiling=="10000"                               and
$air_forecast_ceiling=="noceiling" ) {
       $ceil_less=$ceil_less+1;
     }
     if($air_observe_ceiling=="noceiling"                           and
$air_forecast_ceiling=="0-2000" ) {
       $ceil_less=$ceil_less+1;
     }
     if($air_observe_ceiling=="noceiling"                           and
$air_forecast_ceiling=="2000-10000" ) {
       $ceil_less=$ceil_less+1;
     }
     if($air_observe_ceiling=="noceiling"                           and
$air_forecast_ceiling=="10000" ) {
       $ceil_less=$ceil_less+1;
     }
     if ($air_forecast_visibility==$air_observe_visibility) {
     $vis_correct=$vis_correct+1;
     }
     if($air_observe_visibility=="0-3"  and  $air_forecast_visibility=="3
or greater" ) {
       $vis_less=$vis_less+1;
     }
```

```
    if($air_observe_visibility=="3        or        greater"        and
$air_forecast_visibility=="0-3" ) {
      $vis_greater=$vis_greater+1;
    }
    //
    //ANALYSIS OF TAWS DATA
    //
    $ir_sensor=$row['ir_sensor'];
    $ir_out_acc=$row['ir_out_acc'];
    $ir_out_20plus=$row['ir_out_20plus'];
    $ir_out_20less=$row['ir_out_20less'];
    if ($ir_sensor=="atflir") {
       if ($ir_out_acc=="yes") {
        $atflir_acc=$atflir_acc+1;
       }
       if ($ir_out_20plus=="yes") {
        $atflir_plus=$atflir_plus+1;
       }
       if ($ir_out_20less=="yes") {
        $atflir_less=$atflir_less+1;
       }
    }
    if ($ir_sensor=="lantirn") {
       if ($ir_out_acc=="yes") {
        $lantirn_acc=$lantirn_acc+1;
       }
       if ($ir_out_20plus=="yes") {
        $lantirn_plus=$lantirn_plus+1;
       }
       if ($ir_out_20less=="yes") {
        $lantirn_less=$lantirn_less+1;
       }
    }
    if ($ir_sensor=="nighthawk") {
       if ($ir_out_acc=="yes") {
        $nighthawk_acc=$nighthawk_acc+1;
       }
       if ($ir_out_20plus=="yes") {
        $nighthawk_plus=$nighthawk_plus+1;
       }
       if ($ir_out_20less=="yes") {
        $nighthawk_less=$nighthawk_less+1;
       }
    }

    $ir_plan_none=$row['ir_plan_none'];
    $ir_plan_poss=$row['ir_plan_poss'];
    $ir_plan_thermal=$row['ir_plan_thermal'];
    $ir_plan_taws=$row['ir_plan_taws'];
    $ir_plan_other=$row['ir_plan_other'];
    if ($ir_plan_none=="yes") {
      $ir_none=$ir_none+1;
    }
    if ($ir_plan_poss=="yes") {
      $ir_poss=$ir_none+1;
    }
    if ($ir_plan_thermal=="yes") {
```

```
      $ir_thermal=$ir_none+1;
    }
    if ($ir_plan_taws=="yes") {
      $ir_taws=$ir_none+1;
    }
    if ($ir_plan_other=="yes") {
      $ir_other=$ir_none+1;
    }
  }
//
//DETERMINE THE PERCENT OF MISSIONS IMPACTED
//
$missions_impacted=round($impact_yes/$mission_counter*100);

/*-------------------------------------------------
IMPACT BY WEATHER TYPE CALCULATIONS (QUESTION #4)
-------------------------------------------------*/
$total_wx_impacts=$surf_wind+$aloft_wind+$alt+$cloud+$vis_ds+$vis_fog+$
vis_na+$vis_haze+$vis_pr;
$vis_other=$vis_na+$vis_haze+$vis_pr;
//
//calculate impact per mission
//
$per_mission_surf_wind=round($surf_wind/$total_wx_impacts*100);
$per_mission_aloft_wind=round($aloft_wind/$total_wx_impacts*100);
$per_mission_alt=round($alt/$total_wx_impacts*100);
$per_mission_cloud=round($cloud/$total_wx_impacts*100);
$per_mission_vis=round($vis/$total_wx_impacts*100);
$per_mission_vis_other=round($vis_other/$total_wx_impacts*100);
$per_mission_vis_ds=round($vis_ds/$total_wx_impacts*100);
$per_mission_vis_fog=round($vis_fog/$total_wx_impacts*100);
$per_mission_therm=round($therm/$total_wx_impacts*100);
$per_mission_other_impact=round($other_impact/$total_wx_impacts*100);

/*--------------------------------------------------------
INITIAL TEAM PLANNING CHANGES CALCULATIONS (QUESTION #5)
--------------------------------------------------------*/
$total_changes=$none_changed+$delay+$wep_wind+$wep_vis+$other_changed;
//
//calculate changes per mission
//
$per_none_changed=round($none_changed/$total_changes*100);
$per_delay=round($delay/$total_changes*100);
$per_wep_wind=round($wep_wind/$total_changes*100);
$per_wep_vis=round($wep_vis/$total_changes*100);
$per_other_changed=round($other_changed/$total_changes*100);

/*-----------------------------------------
FORECAST ACCURACY CALCULATIONS (QUESTION #6)
-----------------------------------------*/
$total=$correct+$nochange+$wrong_unnec+$wrong_nec+$unknown+$other_verf+
$no3a;
$per_no3a=round($no3a/$total*100);
$per_correct=round($correct/$total*100);
$per_nochange=round($nochange/$total*100);
$per_wrong_unnec=round($wrong_unnec/$total*100);
$per_wrong_nec=round($wrong_nec/$total*100);
```

```
$per_unknown=round($unknown/$total*100);
$per_other_verf=round($other_verf/$total*100);

/*------------------------------------------
WEATHER IMPACTS CALCULATIONS (QUESTION #7)
------------------------------------------*/

$per_mission_none=round($none/$mission_counter*100);
$per_mission_delay=round($delay_impact/$mission_counter*100);
$per_mission_canx=round($canx/$mission_counter*100);
$per_mission_sched_other=round($sched_other/$mission_counter*100);
$per_mission_lowwar=round($lowwar/$mission_counter*100);
$per_mission_highwar=round($highwar/$mission_counter*100);
$per_mission_splitwar=round($splitwar/$mission_counter*100);
$per_mission_war_other=round($war_other/$mission_counter*100);
$per_mission_partial_nostrike=round($partial_nostrike/$mission_counter*
100);
$per_mission_partial_nobombs=round($partial_nobombs/$mission_counter*10
0);
$per_mission_partial_missed=round($partial_missed/$mission_counter*100)
;
$per_mission_partial_other=round($partial_other/$mission_counter*100);

/*------------------------------------------
AIRFIELD FORECAST CALCULATIONS (QUESTION #8)
------------------------------------------*/
$per_wind_correct=round($wind_correct/$mission_counter*100);
$per_wind_less=round($wind_less/$mission_counter*100);
$per_wind_greater=round($wind_greater/$mission_counter*100);
$per_ceil_correct=round($ceil_correct/$mission_counter*100);
$per_ceil_less=round($ceil_less/$mission_counter*100);
$per_ceil_greater=round($ceil_greater/$mission_counter*100);
$per_vis_correct=round($vis_correct/$mission_counter*100);
$per_vis_less=round($vis_less/$mission_counter*100);
$per_vis_greater=round($vis_greater/$mission_counter*100);

/*------------------------------------------
TAW'S PERFORMANCE CALCULATIONS (QUESTION #9)
------------------------------------------*/
$total_atflir=$atflir_acc+$atflir_plus+$atflir_less;
//
//use if else statement to calculate percentages
//
if ($total_atflir=="0") {
   $per_atflir_acc=0;
   $per_atflir_plus=0;
   $per_atflir_less=0;
} else {
   $per_atflir_acc=$atflir_acc/$mission_counter*100;
   $per_atflir_acc=round($per_atflir_acc);
   $per_atflir_plus=$atflir_plus/$mission_counter*100;
   $per_atflir_plus=round($per_atflir_plus);
   $per_atflir_less=$atflir_less/$mission_counter*100;
   $per_atflir_less=round($per_atflir_less);
}
//use if else statement to calculate percentages to ensure
//no division by zero
```

```
$total_lantirn=$lantirn_acc+$lantirn_plus+$lantirn_less;
if ($total_lantirn=="0") {
   $per_lantirn_acc=0;
   $per_lantirn_plus=0;
   $per_lantirn_less=0;
} else {
   $per_lantirn_acc=$lantirn_acc/$mission_counter*100;
   $per_lantirn_acc=round($per_lantirn_acc);
   $per_lantirn_plus=$lantirn_plus/$mission_counter*100;
   $per_lantirn_plus=round($per_lantirn_plus);
   $per_lantirn_less=$lantirn_less/$mission_counter*100;
   $per_lantirn_less=round($per_lantirn_less);

}
//use if else statement to calculate percentages to ensure
//no division by zero
$total_nighthawk=$nighthawk_acc+$nighthawk_plus+$nighthawk_less;
if ($total_nighthawk=="0") {
   $per_nighthawk_acc=0;
   $per_nighthawk_plus=0;
   $per_nighthawk_less=0;
} else {
   $per_nighthawk_acc=$nighthawk_acc/$mission_counter*100;
   $per_nighthawk_acc=round($per_nighthawk_acc);
   $per_nighthawk_plus=$nighthawk_plus/$mission_counter*100;
   $per_nighthawk_plus=round($per_nighthawk_plus);
   $per_nighthawk_less=$nighthawk_less/$mission_counter*100;
   $per_nighthawk_less=round($per_nighthawk_less);

}
/* TO DISPLAY RESULTS THE HTML IS EMBEDDED WITH ECHO STATEMENTS
INTO THE PHP TO ALLOW DIRECT DISPLAY OF THE GRAPHICS AND VARIABLES*/
//
//DISPLAY OF AIRWING ID AND PRIMARY METRICS
//
echo" <font face='Arial'><br>
<table align='center'>
  <tr>
    <td><b>METRIC REPORT FOR AIRWING - $airwing_id </b> </td>
  </tr>
</table>
<br>
<table width='80%' >
  <tr>
    <td width='55%'><b>1. EVENTS IN THIS STUDY </b></td>
    <td> $mission_counter</td>
  </tr>
  <tr>
    <td width='55%'><b>2. EVENTS IMPACTED BY WEATHER</b></td>
    <td>  $impact_yes</td>
  </tr>
  <tr>
    <td    width='55%'><b>3.    PERCENT    OF    EVENTS    IMPACTED    BY
WEATHER</b></td>
    <td>  $missions_impacted </td>
  </tr>
</table>";
```

```
/*-------------------------------------------------
DISPLAYS QUESTION 4: IMPACT BY WEATHER TYPE
--------------------------------------------------*/
echo"
<br>
<table width='100%'>
  <tr>
     <B>4. IMPACT BY WEATHER TYPE</BR>
  </tr>
  <tr>
    <td width='40%'>Excessive Surface Wind</td>
    <td>$surf_wind</td>
    <td>$per_mission_surf_wind %</td>
  </tr>
  <tr>
    <td width='40%'>Excessive Winds Aloft</td>
    <td>$aloft_wind</td>
    <td>$per_mission_aloft_wind %</td>
  </tr>
  <tr>
    <td width='40%'>Altitude Restrictions</td>
    <td>$alt</td>
    <td>$per_mission_alt %</td>
  </tr>
  <tr>
    <td width='40%'>Cloud Thickness/Layers</td>
    <td>$cloud</td>
    <td>$per_mission_cloud %</td>
  </tr>
  <tr>
    <td width='40%'>Reduced Visibility due to Dust</td>
    <td>$vis_ds</td>
    <td>$per_mission_vis_ds%</td>
  </tr>
  <tr>
    <td width='40%'>Reduced Visibility to Fog</td>
    <td>$vis_fog</td>
    <td>$per_mission_vis_fog%</td>
  </tr>
  <tr>
    <td width='40%'>Reduced Visibility due to Other</td>
    <td>$vis_other</td>
    <td>$per_mission_vis_other%</td>
  </tr>
</table>
";
//
//INSERTS GRAPH INTO WEB PAGE USING CHARTS.PHP AND CHARTS.SWF PROGRAMS
//
include "charts.php";
//
//POSITIONS CHART
//
echo"<table width='80%'>
  <tr>
    <td>";
```

```
echo              InsertChart              (              "charts.swf",
"report_negimpact.php?surf_wind=$per_mission_surf_wind
&aloft_wind=$per_mission_aloft_wind&alt=$per_mission_alt&cloud=$per_mis
sion_cloud
&vis_ds=$per_mission_vis_ds&vis_fog=$per_mission_vis_fog&vis_other=$per
_mission_vis_other",400,400,"FFFFFF");
/*-------------------------------------------------
DISPLAYS QUESTION 5: INTIAL TEAM PLANNING CHANGES
-------------------------------------------------*/
echo"</td>
</tr>
</table>
<br>
<table width='100%'>
  <tr>
     <B>5. INITIAL TEAM PLANNING CHANGES</BR>
  </tr>
  <tr>
    <td width='40%'>No changes required </td>
    <td>$none_changed</td>
    <td>$per_none_changed %</td>
  </tr>
  <tr>
    <td width='40%'>Event Delayed/Rescheduled</td>
    <td>$delay</td>
    <td>$per_delay %</td>
  </tr>
  <tr>
    <td width='40%'>Weapons change for High Winds</td>
    <td>$wep_wind</td>
    <td>$per_wep_wind %</td>
  </tr>
  <tr>
    <td width='40%'>Weapon changed for visibility and or ceiling</td>
    <td>$wep_vis</td>
    <td>$per_wep_vis %</td>
  </tr>
  <tr>
    <td width='40%'>Other     </td>
    <td>$other_changed</td>
    <td>$per_other_changed%</td>
  </tr>

</table>";
echo"<table width='80%'>
  <tr>
    <td>";
echo              InsertChart              (              "charts.swf",
"report_change.php?none_changed=$none_changed
&delay=$delay&wep_wind=$wep_wind&wep_vis=$wep_vis
&other_changed=$other_changed",400,400,"FFFFFF");
/*-------------------------------------------------
DISPLAYS QUESTION 6: FORECAST ACCURACY
-------------------------------------------------*/
echo"</td>
</tr>
</table>
```

```
<table width='100%'>
  <tr>
     <B>6. FORECASTER ACCURACY </BR>
  </tr>
  <tr>
    <td width='50%'>No changes were required during team planning.
</td>
    <td>$no3a</td>
    <td>$per_no3a %</td>
  </tr>
  <tr>
    <td width='50%'>Weather was forecasted
correctly.<br>      
    <font size='-1'> Change was correct decision</font></td>
    <td>$correct</td>
    <td>$per_correct %</td>
  </tr>
  <tr>
    <td width='50%'>Weather was forecasted
correctly.<br>      
     <font size='-1'>Mission planner believed accurate forecast but
made no change</font></td>
    <td>$nochange</td>
    <td>$per_nochange %</td>
  </tr>
  <tr>
    <td width='50%'>Weather forecast was
wrong.<br>      
    <font size='-1'>Change was unnecessary. Forecast falsely steered
mission<br>
           plan to be over conservative.
</td>
    </font><td>$wrong_unnec</td>
    <td>$per_wrong_unnec %</td>
  </tr>
  <tr>
    <td width='50%'>Weather forecast was wrong.
<br>      
    <font size='-1'>Change was required as the weather impact was
greater than forecasted </td>
    </font><td>$wrong_nec</td>
    <td>$per_wrong_nec%</td>
  </tr>
  <tr>
    <td width='50%'>Not enough information to know if decision was good
or bad.</td>
    <td>$unknown</td>
    <td>$per_unknown%</td>
  </tr>
  <tr>
    <td width='50%'>Other     </td>
    <td>$other_verf</td>
    <td>$per_other_verf%</td>
  </tr>
</table>
<table width='80%'>
  <tr>
```

```
    <td>";
/*------------------------------------------------
DISPLAYS QUESTION 7: WEATHER IMPACTS
------------------------------------------------*/
echo InsertChart ( "charts.swf", "results_change.php?per_no3a=$per_no3a
&per_correct=$per_correct&per_nochange=$per_nochange&per_wrong_unnec=$p
er_wrong_unnec
&per_wrong_nec=$per_wrong_nec&per_unknown=$per_unknown&per_other=$per_o
ther_verf",900,400,"FFFFFF");
echo"</td>
</tr>
</table>
<table width='100%'>
  <tr>
     <B>7. WEATHER IMPACTS  </BR>
  </tr>
  <tr>
    <td width='40%'>No Impacts</td>
    <td>$none</td>
    <td>$per_mission_none %</td>
  </tr>
  <tr>
  <tr>
    <td width='40%'>Total Event Delayed/Rescheduled </td>
    <td>$delay_impact</td>
    <td>$per_mission_delay %</td>
  </tr>
    <td width='40%'>Entire event canceled       </td>
    <td>$canx</td>
    <td>$per_mission_canx %</td>
  </tr>
  <tr>
    <td width='40%'>Low war </td>
    <td>$lowwar</td>
    <td>$per_mission_lowwar %</td>
  </tr>
  <tr>
    <td width='40%'>High war  </td>
    <td>$highwar</td>
    <td>$per_mission_highwar %</td>
  </tr>
  <tr>
    <td width='40%'>Split war  </td>
    <td>$splitwar</td>
    <td>$per_mission_splitwar%</td>
  </tr>
  <tr>
    <td width='40%'>Non strike aircraft did not complete mission </td>
    <td>$partial_nostrike</td>
    <td>$per_mission_partial_nostrike%</td>
  </tr>
  <tr>
    <td width='40%'>Bomber did not drop </td>
    <td>$partial_nobombs</td>
    <td>$per_mission_partial_nobombs%</td>
  </tr>
  <tr>
```

```
    <td width='40%'>Bombs missed target </td>
    <td>$partial_missed</td>
    <td>$per_mission_partial_missed%</td>
  </tr>
  <tr>
    <td width='40%'>Other partial mission </td>
    <td>$partial_other</td>
    <td>$per_mission_partial_other%</td>
  </tr>
</table>";
echo"<table width='100%' align='center'>
  <tr>
    <td>";
echo              InsertChart              (              "charts.swf",
"results_impact.php?delay=$per_mission_delay
&canx=$per_mission_canx&lowwar=$per_mission_lowwar
&highwar=$per_mission_highwar&splitwar=$per_mission_splitwar
&partial_nostrike=$per_mission_partial_nostrike&partial_nobombs=$per_mi
ssion_partial_nobombs
&partial_missed=$per_mission_partial_missed&partial_other=$per_mission_
partial_other
&none=$per_mission_none",600,400,"FFFFFF");
/*-------------------------------------------------
DISPLAYS QUESTION 8: FORECASTER VERIFICATION
-------------------------------------------------*/
echo"</td>
</tr>
</table>
<table width='100%'>
  <tr>
     <B>8. FORECASTER VERIFICATION  </BR>
  </tr>
  <tr>
    <td width='30%'>Winds = Forecast</td>
    <td>$wind_correct</td>
    <td>$per_wind_correct %</td>
  </tr>
  <tr>
  <tr>
    <td width='30%'>Winds > Forecast </td>
    <td>$wind_greater</td>
    <td>$per_wind_greater %</td>
  </tr>
    <td width='30%'>Winds < Forecast      </td>
    <td>$wind_less</td>
    <td>$per_wind_less %</td>
  </tr>
  <tr>
    <td width='30%'></td>
    <td></td>
    <td></td>
  </tr>
  <tr>
    <td width='30%'>Ceiling = Forecast</td>
    <td>$ceil_correct</td>
    <td>$per_ceil_correct %</td>
  </tr>
```

```
  <tr>
  <tr>
    <td width='30%'>Ceiling > Forecast </td>
    <td>$ceil_greater</td>
    <td>$per_ceil_greater %</td>
  </tr>
    <td width='30%'>Ceiling < Forecast    </td>
    <td>$ceil_less</td>
    <td>$per_ceil_less %</td>
  </tr>
  <tr>
    <td width='30%'></td>
    <td></td>
    <td></td>
  </tr>
  <tr>
    <td width='30%'>Visibility = Forecast</td>
    <td>$vis_correct</td>
    <td>$per_vis_correct %</td>
  </tr>
  <tr>
  <tr>
    <td width='30%'>Visibility > Forecast </td>
    <td>$vis_greater</td>
    <td>$per_vis_greater %</td>
  </tr>
    <td width='30%'>Visibility < Forecast       </td>
    <td>$vis_less</td>
    <td>$per_vis_less %</td>
  </tr>
</table><br>
  <table width='100%'>
  <tr>
     <B>9a. TAWS ACCURACY (AT FLIR)</B>
  </tr>
  <tr>
    <td width='30%'>WOF = TAWS Prediction</td>
    <td>$atflir_acc</td>
    <td>$per_atflir_acc %</td>
  </tr>
  <tr>
  <tr>
    <td width='30%'>WOF > TAWS Prediction </td>
    <td>$atflir_plus</td>
    <td>$per_atflir_plus %</td>
  </tr>
    <td width='30%'>WOF < TAWS Prediction       </td>
    <td>$atflir_less</td>
    <td>$per_atflir_less %</td>
  </tr><br>
  <tr>
    <td width='30%'><b>9b. TAWS ACCURACY (LANTRN)</b></td>
    <td></td>
    <td></td>
  </tr>
  <tr></tr>
<tr>
```

```
    <td width='30%'>WOF = TAWS Prediction</td>
    <td>$lantirn_acc</td>
    <td>$per_lantirn_acc %</td>
  </tr>
  <tr>
  <tr>
    <td width='30%'>WOF > TAWS Prediction </td>
    <td>$lantirn_plus</td>
    <td>$per_lantirn_plus %</td>
  </tr>
    <td width='30%'>WOF < TAWS Prediction       </td>
    <td>$lantirn_less</td>
    <td>$per_lantirn_less %</td>
  </tr>
  <tr>
    <td width='30%'><b>9c. TAWS ACCURACY (NIGHT HAWK)</b></td>
    <td></td>
    <td></td>
  </tr>
  <tr>
    <td width='30%'>WOF = TAWS Prediction</td>
    <td>$nighthawk_acc</td>
    <td>$per_nighthawk_acc %</td>
  </tr>
  <tr>
  <tr>
    <td width='30%'>WOF > TAWS Prediction </td>
    <td>$nighthawk_plus</td>
    <td>$per_nighthawk_plus %</td>
  </tr>
    <td width='30%'>WOF < TAWS Prediction       </td>
    <td>$nighthawk_less</td>
    <td>$per_nighthawk_less %</td>
  </tr>
</table><br>
<table width='100%'>
  <tr>
     <B>10. TAWS IMPACT TO MISSION PLANNING  </BR>
  </tr>
  <tr>
    <td                      width='40%'>No                        changes
required.<br>      
    <font  size='-1'>  There  is  no  forecast  impact  to  the  sensor.
</font></td>
    <td>$ir_none</td>

  </tr>
  <tr>
    <td           width='40%'>No           changes           required.
<br>      
    <font  size='-1'>Possible  IR  Sensor  impact  for  visibility/ceiling
noted earlier.</font></td>
    <td>$ir_poss</td>
    </tr>
  <tr>
    <td width='40%'>Mission change for thermal crossover.</td>
    <td>$ir_thermal</td>
```

```
  </tr>
  <tr>
    <td  width='40%'>Attack  heading  change  per  TAWS  ranges  prediction.
</td>
    <td>$ir_taws</td>
  </tr>
  <tr>
    <td width='40%'>Other</td>
    <td>$ir_other</td>
  </tr>
</table>";
?>

<!--DISPLAY CONTACT INFORMATION AT BOTTOM OF PAGE -->
<br><br><br><br><br><br><br>
<p align="center">Points of Contact:<br>
   Tom Murphree, Ph.D. <i>murphree@nps.edu</i><br>
   Mark Butler, LCDR, USN <i>mdbutler@nps.edu</i><br>
<br><br></p>
<a       href='http://wx.met.nps.navy.mil/~mdbutler/fallon/metrics.htm'>
Return to Main Menu</a>
</BODY>
</HTML>
```

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